NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

AN APPLICATION OF MULTIDIMENSIONAL SCALING
TO DESCRIBE STRESS AMONG NAVAL
HELICOPTER PILOTS

by

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March 1986

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URITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
SECURITY CLASSIFICATION AUTHORITY	3 DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited
DECLASSIFICATION/DOWNGRADING SCHEDULE	
ERFORMING ORGANIZATION REPORT NUMBER(S)	5 MONITORING ORGANIZATION REPORT NUMBER(S)

NAME OF PERFORMING ORGANIZATION aval Postgraduate School	6b OFFICE SYMBOL (If applicable) Code 55	7a. NAME OF MONITORING ORGANIZATION Naval Postgraduate School
ADDRESS (City, State, and ZIP Code) onterey, California 93943-5000		7b ADDRESS (City, State, and ZIP Code) Monterey, California 93943-5000
NAME OF FUNDING/SPONSORING ORGANIZATION	8b OFFICE SYMBOL (If applicable)	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER

ADDRESS (City, State, and ZIP Code)

10 SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO	PROJECT NO	TASK NO	WORK UNIT ACCESSION NO

TITLE (Include Security Classification)
AN APPLICATION OF MULTIDIMENSIONAL SCALING TO DESCRIBE STRESS AMONG NAVAL HELICOPTER PILOTS

PERSONAL AUTHOR(S) Walston, Thomas L. III

TYPE OF REPORT	13b TIME COVERED	14 DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
aster's Thesis	FROM ______ TO ______	1986, March	96

SUPPLEMENTARY NOTATION

COSATI CODES			18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Stress, Helicopter Pilots, Multidimensional Scaling

ABSTRACT (Continue on reverse if necessary and identify by block number)

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DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21 ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED	
NAME OF RESPONSIBLE INDIVIDUAL Professor D. E. Neil	22b TELEPHONE (Include Area Code) (408) 646-2419	22c OFFICE SYMBOL 55NI

FORM 1473, 84 MAR   83 APR edition may be used until exhausted
All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE

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An Application of Multidimensional Scaling to Describe Stress Among Naval Helicopter Pilots

by

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MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
March 1986

ABSTRACT

The technique of multidimensional scaling is used in an attempt to determine any patterns utilized by Naval helicopter pilots when grouping a given set of stressors. Both grouping data and ranking data were collected and analyzed from a survey among pilots. Information gained through the ranking data consist of perceptions of the helicopter pilots on how the stressors affect certain performance aspects. Numerical output, as well as graphical plots, were generated to reflect these perceptions.

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I. INTRODUCTION

Naval aviation, in general, is a high-stress environment. The variety of stresses associated with flying an aircraft have an impact on the effectiveness with which that task is performed. Helicopter flying has stressful situations, many of which, are unlike those of other aircraft. The missions, flight characteristics, and environment all contribute to these difficulties. It is important for the pilot to be aware of these stressful conditions in order to capably operate the helicopter.

"A stressful situation occurs when there is a substantial imbalance between the demands imposed on an organism by the environment and the organism's capability to successfully handle those demands" [Ref. 1:p. 604]. The demand which causes stress is called a stressor. A stressor can range from being an environmental condition such as extreme heat, to a job related event like boredom. Although stressors, and the accompanying stress, are usually thought of in a negative sense, there are positive contributions assosciated with them. In the case of a helicopter pilot, some stress can be helpful in a demanding circumstance. It keeps the pilot alert and ready for action, and prevents boredom and complacency from setting in [Ref. 2:p. 28].

Dr. Hans Selye, a noted authority on stress, theorized that "stress is the nonspecific response of the body to any demand made upon it." [Ref. 3] This theoretical position suggests that, independent of the stressor involved, the body responds with a set of biological events that together form a pattern indicative of stress [Ref. 1:p. 602]. This is Dr. Selye's theory of the General Adaption Syndrome. The syndrome is divided into three stages: alarm reaction, resistance, and exhaustion. As the body perceives the stressor it responds be releasing chemicals into the bloodstream to help blood clotting, metabolism in the muscles of the arms and legs speeds up to prepare for any action required, and heart rate, respiration, blood pressure, and sweating all increase [Ref. 2:p. 28]. This is the alarm reaction stage. The resistance stage is characterized by the body adapting to the stressor, while at the same time exhibiting a decrease in resistance to other stimuli [Ref. 1:p. 602]. The final stage, exhaustion, occurs when there is no relief from the stressor. If stress continues for a period of time, "it can fatigue and later damage the body to the point of disease or dysfunction" [Ref. 4:p. 3].

The arena of helicopter flight presents the pilot with a multitude of stressful situations. Helicopters are generally very noisy, vibrate continuously, and have flying

characteristics which set them apart from other aircraft types. A pilot flying a helicopter must accustom himself to these effects. Since helicopters are versatile aircraft, a tendency to overuse this attribute can increase the amount of stress a pilot has to face. Many instances occur where, during the course of a mission, other commitments are added that often exceed the capability of the pilot and his aircraft. Operating at sea on deployments present stresses which require the pilot to change his eating and sleeping habits. The variability of flight schedules force an ability to eat, at times, on the run or not at all. Sometimes the quality of food eaten lacks the nutritional value needed for coping in a stressful environment. Pilots must be able to sleep at odd hours on an inconsistent basis and in high noise areas. His daily routine conforms to the requirements of the flight schedule. An early morning flight means sleeping during daylight hours while noise from daytime work goes on around him. In the world of the aircraft carrier, with flight operations around the clock, the pilot basically sleeps with an airport above his head. Environmental conditions such as extreme heat or cold are common stresses a pilot may face. Long hot and humid days out in the middle of the Indian Ocean can increase stress, not only in the individual himself, but in his ability to fly the helicopter. Extremes in the environment require an

added awareness of the flight characteristics for those conditions. Lack of exercise is another stress placed upon the helicopter pilot. Pilots must adapt their exercise routine to fit the shipboard environment. Most of these stresses act in combination with one another and can have a detrimental effect on the capability with which the pilot flys his aircraft.

The importance of operating the helicopter safely and effectively should be foremost on the mind of the pilot. Prior to every flight he must leave all problems, causing stress, behind him and concentrate on the task at hand. Taking any of these with him on a flight can lead to distraction, reduced alertness, disorientation during high risk operations, and possibly misinterpreting cues as to what is happening to the aircraft. The cost to the pilot may be that of his life, his crewmen's lives, and the loss of the helicopter.

Solving the problem of stress begins with the identification of those factors which cause the stress. From that point the pilot can determine what effect they have on him and his ability to operate the helicopter, and attempt to handle the stress in a suitable way. With this in mind, the objectives of this research were to:

1) Identify stressors which may affect the performance of naval helicopter pilots.

2) Estimate those stressful conditions which are perceived as having the greatest impact on the performance of the pilot and which aspects of that performance are most affected.

3) Determine a pattern, if any, used by the pilots in grouping the given stressors.

II. METHODOLOGY

A. GENERAL

In determining a method for accomplishing this research, many options existed. The variety of data collection methods and data analysis techniques available allowed for the use of those which best served the objectives of the research. To that end, a set of stressors adequate enough to cover the spectrum of conditions encountered by helicopter pilots was determined. Next, a set of performance aspects that might be affected by stressors were determined. An indication of which stressors had the greatest impact could then be viewed, depending on the aspect. Deciding upon a representative set of pilots was accomplished quite easily using local resources. Once the stressors and helicopter pilots were identified, a means by which to gather the desired stress data was needed. A questionnaire/survey served this purpose well. With the information collected, the final step of analyzing the data was performed using the technique of multidimensional scaling. Contained in this chapter are the details associated with the methodology used in carrying out these steps and ultimately achieving the objectives of this research.

B. STRESSOR SELECTION

The selection criteria for the representative set of stressors consisted of a few meaningful requirements. First, the stressor needed to be one which would likely be encountered by a naval helicopter pilot at sea and would in some way affect his performance. Secondly, the stressor had to be such that it was one that the U.S. Navy had some control over. Stressful life events such as divorce, personal problems at home, and death in the family, for instance, were left out. The number of stressors used in the survey had to be limited in order to gain any insightful information from the helicopter pilots. A large number is difficult to compare with each other; a task which was required of the pilots in this study. The survey utilized 18 stressors, all of which fulfilled the above requirements. A review of a study on stress and sonar operators [Ref. 5: p. 29] aided in the selection of these stressors. The stressors included the following:

- irregular patterns of sleep and meals
- exercise enviroment
- uncomfortable heat
- uncomfortable cold
- noise
- helicopter flight characteristics/vibrations
- role demands

- mission type
- helicopter cockpit, controls, and instrument design
- personal equipment design
- watches, duty, alerts
- night flying
- boredom/monotony
- ground job
- operator overload
- fatigue
- command pressure
- characteristics of person you are flying with

The complete definitions of these stressors as given to the helicopter pilots are contained in Appendix A.

C. PERFORMANCE ASPECTS

Determining the performance aspects required of a pilot necessitated an in-depth look into the procedures involved in flying a helicopter. To fly a helicopter requires a combination of several skills, both physical and mental. The following three items were concluded as being the performance aspects that may be affected by stress. A fourth factor was included to see how overall performance was affected.

PERFORMANCE ASPECTS

- Eye-Hand Coordination
  how stressors affect the physical ability to fly the helicopter

- Alertness/Vigilance
  how stressors affect the ability to stay alert, vigilant to the task at hand

- Thinking/Decision Making
  how stressors affect the ability to think or reason about tasks that need to be performed while flying

- Overall
  how stressors affect the overall ability to fly the helicopter

The complete definitions as given to the pilots are contained in Appendix B.

D. HELICOPTER PILOT SELECTION

The pilots that participated in this research were selected on the basis of mainly two criteria. They had to be U.S. Navy helicopter pilots and they had to have had one tour of duty deployed out at sea. Three different helicopter types were represented among this group. The SH-3 Sea King, flying primarily off of aircraft carriers, the SH-2 Seasprite, flying off of escort and ASW surface ships, and the CH-46 Sea Knight, which fly off of supply type ships, were the models flown by the helicopter pilots interviewed. The breakdown in numbers for each type of helicopter along with the average number of hours of flight time for the pilots was as follows:

9 SH-3 pilots with average number of flight hours equal to 1039

9 SH-2 pilots with average number of flight hours equal to 960

9 CH-46 pilots with average number of flight hours equal to 952

Pilots from East coast and West coast helicopter squadrons were selected. All of the pilots participating were attending the Naval Postgraduate School in Monterey, California at the time the survey was taken.

E. MULTIDIMENSIONAL SCALING

To determine the key underlying characteristics inherent in the set of stressors used for this research, the statistical procedure of multidimensional scaling was used. Multidimensional scaling is a useful mathematical tool that allows for the representation of the similarities of objects spatially as in a map [Ref. 6:p. 3]. According to Torgerson [Ref. 7:p. 248], the problem to be handled by multidimensional scaling procedures is, "given a set of stimuli which vary with respect to an unknown number of dimensions, determine (a) the minimum dimensionality of the set, and (b) scale values on each of the dimensions involved."

The input for this technique is called a proximity. Proximities are numbers which represent the similarity or lack of similarity between two objects. The method of determining the proximity for this research is discussed in the section on dissimilarity measure in this chapter. If objects are judged to be very similar, the output of the multidimensional scaling procedure would represent these as points close to each other in the resultant spatial map. Dissimilar objects would be represented as points far apart

from one another. What is desired here is the configuration of points in the Euclidean space of smallest possible dimension that result in the interpoint distance being monotonically related to the given proximity data [Ref. 8: p. 7]. That is, the interpoint distance, d(ij), must be less than the distance, d(kl), whenever the proximity, s(ij), is larger than the proximity, s(kl), for objects i,j,k,l.

That the distance between the points should correspond to the proximities is a central concept of multidimensional scaling [Ref. 8:p. 19]. An easy method of seeing this correspondence is through use of a scatter diagram, see Figure 2.1. The horizontal axis show the distances, d(ij), while the vertical axis displays the measured proximities. If, for instance, the proximities plotted here are dissimilarities, a large dissimilarity would correspond to a large distance, and small dissimilarities to small distances. If one were to attempt to determine a relationship between the distance and proximity by means of a formula such as, d=f(s), the multidimensional scaling would be metric. The distances in metric scaling preserve the original proximity data in a linear fashion as much as possible [Ref. 6:p. 17]. Nonmetric multidimensional scaling attempts to describe the relationship solely by the fact that a rising (or falling) pattern is desired. Here the

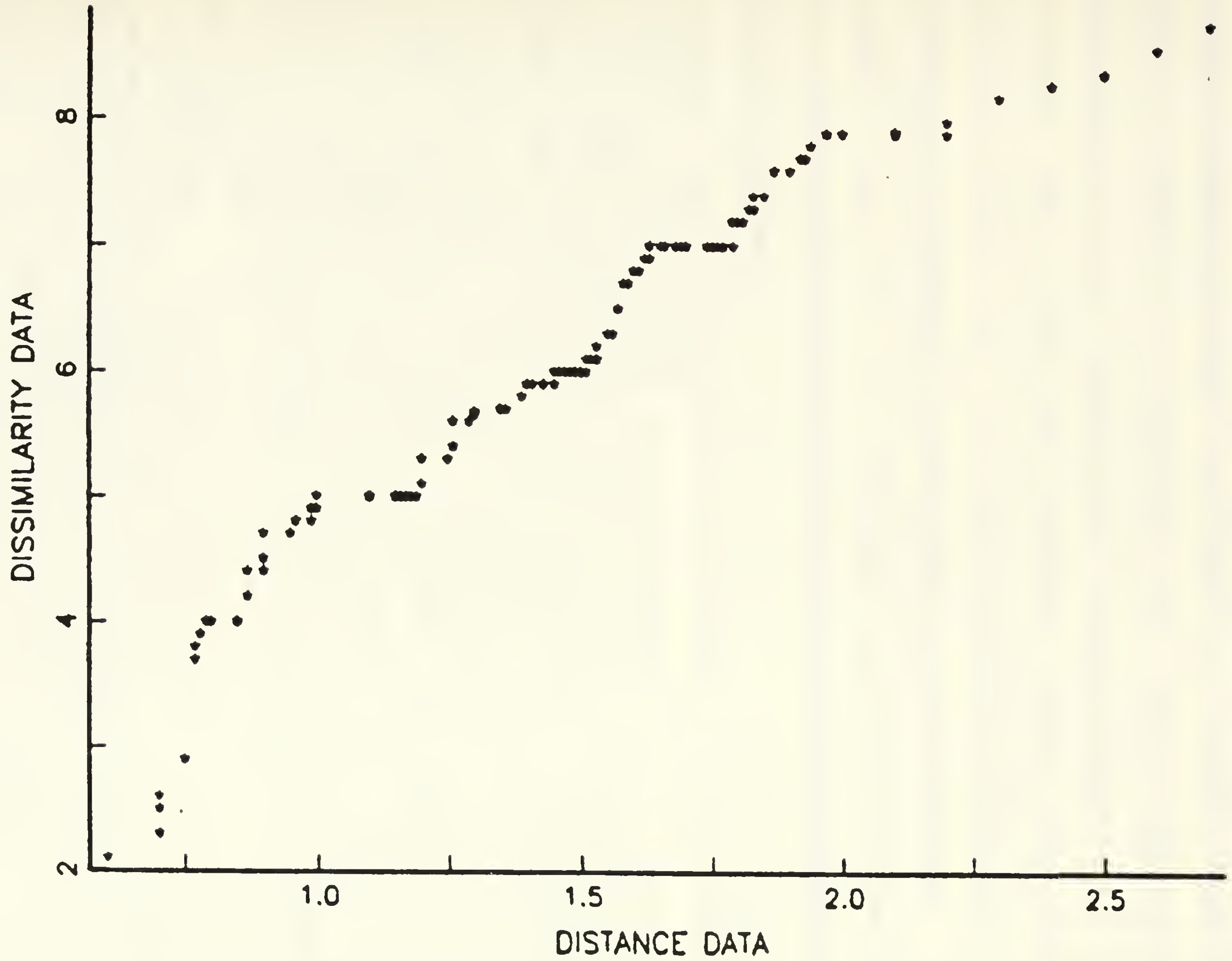

Figure 2.1. Scatter Plot of Distance vs. Dissimilarity

determining factor of whether the points rise or fall is the rank order of the original proximity data. Achieving a perfect fit with a formula to describe a relationship in this case in not common practice. In general, nonmetric scaling provides spaces with better fit in low dimensionality than metric solutions [Ref. 6:p. 6], and this is the method used for this research.

A primary concern when using multidimensional scaling is determining how many dimensions to use. The number of dimensions refer to the number of coordinate axes in the stimulus space. In most cases a representation of the lowest possible dimensionality consistent with the data is desired. Some considerations to inspect prior to choice of dimensionality include that of the residual departure from monotonicity, the representation should be statistically reliable, the representation should be interpretable, and the representation should be readily visualizable [Ref. 8: pp. 9-10]. The residual departure from monotonicity, also known as goodness of fit, is measured by a function called "stress", hereafter referred to as the goodness of fit function to avoid possible confusion. Generally, the goodness of fit function will decrease as the number of dimensions is increased. If the goodness of fit function is plotted against the corresponding number of dimensions, frequently an "elbow" occurs where the curve drops toward

zero and then trails off slowly thereafter. See Figure 2.2. The number of dimensions at this elbow are the maximum normally considered [Ref. 6:p. 11]. As a general rule of thumb, a goodness of fit value of .2 or greater indicates a poor goodness of fit, a value of .1 is fair, a value of .05 is good, .025 is excellent, while a value of 0.0 is considered perfect [Ref. 9:p. 3]. A visual representation is much more accessible to the eye if the dimension is limited to three or less. Therefore, graphical limitations are a major factor if interpretation through this method is to be accomplished.

F. UNCONDITIONAL SORTING

The task of providing inputs for the multidimensional scaling was performed using the technique of unconditional sorting. In this technique the subject is asked to sort the items being scaled by the criterion of similarity of meaning. Items that are perceived to be similar by the subject are placed in the same group. No restrictions are placed on the number of groups or on the number of items in each group.

Unconditional sorting has two qualities which were instrumental in its selection for use in this study. First, it is a quick and easily performed means of gathering data for input into multidimensional scaling algorithms. The helicopter pilots for this survey provided the required data

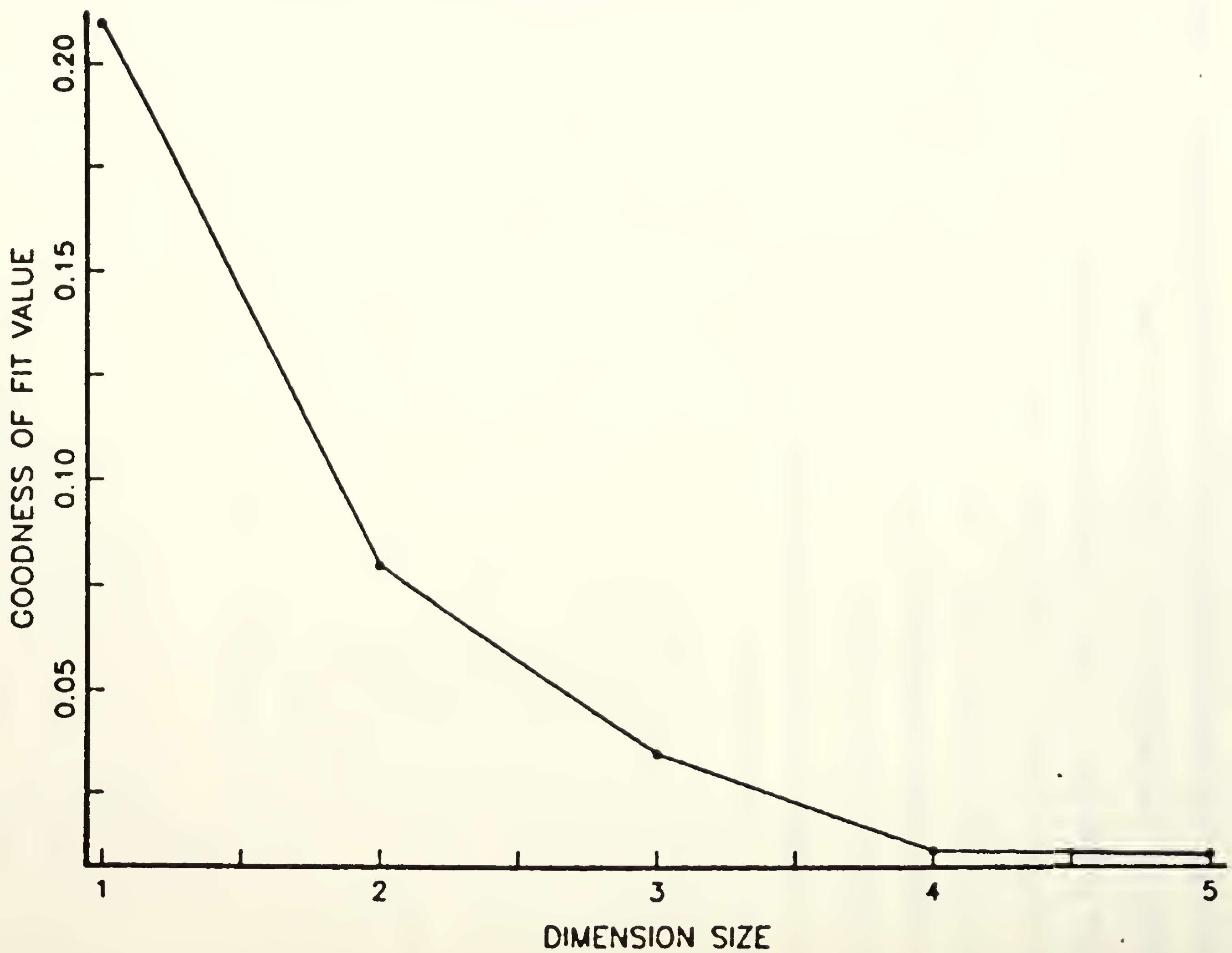

Figure 2.2. Plot of Goodness of Fit vs. Dimension

in less than half an hour. Secondly, this type of sorting "allows the levels of distinction drawn among the stimulus by different subjects to be explicitly controlled in the processing the the results" [Ref. 10]. Individuals vary in the kinds of groupings which they make. Some divide the stimuli into many groups, while others utilize a small number of groups. Unconditional sorting permits the desired level of distinction to be emphasized by the researcher. In this study, the most general dimensions were desired and therefore broad distinctions among the stimuli were emphasized. Unconditional sorting data collected from the pilots is contained in Appendix J.

G. DISSIMILARITY MEASURE

With the sorted data collected, a measure of dissimilarity was needed for input to multidimensional scaling. A measure defined by Burton [Ref. 11:pp. 411-416] compensates for differences in the sizes of the individual groups sorted by the subjects. This measure is metric and is a sum of the dissimilarity measures for the individual subjects. Metric implies that the dissimilarity measure is always positive, symmetric, and conforms to the triangle inequality.

The distance between stimulus elements x and y will be, for this measure, the sum of the distances between x and y for all subjects. For each subject, i, x and y are either in the same cell, c(ij), where j is the jth cell of subject

i, or are in different cells. The size of cell c(ij) can vary from 2 to N, (N is the number of stimulus items). A small cell size implies that the subject has made a relatively fine distinction between members of cell c(ij) and all other cells. In this case the average similarity among members of cell c(ij) is large. Since this is a sum of individual similarities, some of these may be small even though the average similarity is large. For large cell sizes, a broad distinction is made and the average similarity associated with its members is small although some of the individual similarities could be large. Burton [Ref. 11:p. 411] concludes that "a most accurate measure of similarity would compute a larger increment to similarity when two elements are in a small cell than when they are in a large cell." Therefore larger cells will have a lower average similarity than small cells. As a carry over from this, an accurate distance measure should compute a small decrement to distance for small cells and a larger decrement to distance for larger cells. Adjustments are also made where items x and y are in different cells.

A concept defined by Boorman and Arabie [Ref. 8:p. 235] which is central to this measure is that of the height of a partition. A partition is the grouping of the set of stimulus elements. The height of a partition ranges from zero to one, where a partition of height zero has one cell

for each stimulus element, and a height of one implies all stimulus elements are in the same cell. It is basically the number of pairs of elements which are placed together in cells divided by the total number of pairs of elements in the stimulus set.

Burton's dissimilarity measure is defined as follows:

Terminology,

P(i) = partition induced by subject i

T = the number of subjects doing the sorting

|P(i)| = the number of cells in the partition for subject i

c(ij) = cell j from subject i

N(ij) = size of cell c(ij)

S = the set of stimulus elements

N = number of stimulus elements in S

The metric dissimilarity measure, $Dx,y = \sum_{i=1}^{T} D(i)x,y$

D(i)x,y is defined by

D(i)x,y = A(ij) if subject i placed x and y in c(ij)

= B(i) if subject i placed x and y in different cells

= 0 if x = y

with constraints

$B(i) \geq \max A(ij)$

$A(ij) > 0$

The height of P(i), H(i) is defined by

$$H(i) = \sum_{j=1}^{|P_i|} H(ij) = \frac{\sum_{j=1}^{|P_i|} (N(ij))! \,/\, \{2!(N(ij)-2)!\}}{N! \,/\, \{2!(N-2)!\}}$$

As defined previously, H(i) equals zero if all elements of S are in different cells and equals one if the elements are in the same cell. H(ij) is the contribution to H(i) for c(ij) and is the proportion of pairs of elements which are found within c(ij). The proportion of pairs not found in the same cell is defined as Q(i) = 1 - H(i).

The similarity measure for each subject, S(i)x,y, is defined by

$$\begin{aligned} S(i)x,y &= -\mathrm{Log}_2 H(ij) && \text{if } x \text{ and } y \text{ are in } c(ij) \\ &= \mathrm{Log}_2 Q(i) && \text{if } x \text{ and } y \text{ are in different cells for subject } i \\ &= \mathrm{Log}_2(N!/(2!(N-2)!) + e) && \text{if } x = y \end{aligned}$$

'e' is any number greater than zero. A postive value for e ensures that the similarity of an element to itself will be greater than the maximum similarity of an element to any other element. A value of one was used for this study.

$$C = \mathrm{Log}_2(N!/(2!(N-2)!) + 1)$$

Now

$$D(i)x,y = C - S(i)x,y$$

from this formula,

$$A(ij) = C + \text{Log}_2 H(ij)$$

$$B(i) = C - \text{Log}_2(1 - H(i))$$

The dissimilarity measure is defined as $Dx,y = \sum_{i=1}^{T} D(i)x,y$. This is the method used to determine the input matrix for multidimensional scaling. The matrix consists of only the lower half of the complete matrix, without the diagonal elements. The upper half of the matrix is a mirror image of the lower half as the dissimilarity between x and y is the same as the dissimilarity for y and x. The diagonal is left off since the values are all zeros, corresponding to the definition of D(i)x,y. The dissimilarity matrix used for this study is shown in Table I. Results of this input are discussed in Chapter III.

H. QUESTIONNAIRE/SURVEY

Collecting the required data was accomplished using a survey among designated helicopter pilots. Each helicopter pilot was given a kit consisting of an instruction sheet, as in Appendix B, an answer sheet, as in Appendix C, and a set of index cards, as in Appendix A. The instruction sheet described the required tasks to be completed and gave definitions of the performance aspects. Contained on the answer sheet was ample room for the ranking data, the

sorting data, and the biographical data. The 18 index cards each included the name of a stressor, its definition, and a mnemonic code identifying the stressor for easy transfer to the answer sheet.

The first task to be performed by the helicopter pilot was the ranking of the stressors. Each stressor was to be ranked according to the specified performance aspect. There were four separate rankings, one for each of the performance aspects. A rank of one corresponded to that of the most stressful, while a rank of eighteen was the least stressful. The sorting task was next and the pilots were instructed to sort the stimuli according to the perceived similarity of the stressors. Finally, a set of biographical questions were completed for background information purposes. There was no time limit set for the completion of the survey and in no case did the required time exceed thirty minutes.

III. RESULTS

A. GENERAL

This chapter deals with the results gathered from the helicopter pilot stress survey. The output of the multi-dimensional scaling is analyzed, as is the data obtained from the stressor rankings.

B. MULTIDIMENSIONAL SCALING RESULTS

The dissimilarity matrix for the eighteen stressors, Table I, was used as input to the multidimensional scaling program KYST [Ref. 12]. Format used for input of the program is given in Appendix D. Solutions were generated for dimensions one to five, output for dimension four is shown in Table II, while the outputs are contained in Appendix E.

Determination of which dimension to use was made by analyzing the plot of the goodness of fit function against the dimensionality, shown in Figure 3.1. In this case the elbow of the curve occurs near dimension four, which corresponds to a goodness of fit value of .011. Using Kruskal's [Ref. 9:p. 3] rule of thumb, a goodness of fit value lower than .025 is considered better than excellent.

The four dimensional solution from KYST is graphically displayed in Appendix F. Coordinates of these plots are shown in Table II.

TABLE I

DISSIMILARITY MATRIX FOR THE STRESSORS

1.17																
1.87	1.88															
1.87	1.88	0.58														
2.00	1.93	1.28	1.28													
2.03	2.03	1.81	1.81	1.15												
2.03	1.99	1.85	1.85	1.72	1.21											
1.37	1.64	2.00	2.00	2.00	2.03	1.99										
1.95	1.92	1.90	1.90	1.98	1.87	1.92	1.95									
1.46	1.69	1.84	1.84	2.00	2.03	1.91	1.61	1.86								
1.94	1.90	2.03	2.03	2.03	2.03	1.96	1.34	2.03	1.95							
1.84	1.95	1.93	1.93	1.95	1.98	1.98	1.88	1.25	1.58	2.03						
0.93	1.40	1.78	1.78	2.00	2.03	2.03	1.52	1.92	1.42	1.99	1.71					
1.99	1.92	2.03	2.03	2.03	2.03	1.96	1.54	2.03	1.90	0.99	2.03	1.99				
1.99	1.85	2.03	2.03	1.93	1.89	1.91	1.92	1.28	1.86	1.91	1.63	1.99	1.77			
2.03	1.95	2.03	2.03	2.03	2.03	1.96	1.58	2.03	1.90	1.16	2.03	2.03	0.82	1.85		
2.03	2.03	1.86	1.86	1.67	1.21	0.75	2.03	1.94	1.99	1.99	1.98	2.03	1.99	1.89	1.99	
2.03	1.98	1.95	1.98	1.83	1.89	1.98	1.98	1.74	1.91	1.83	1.82	1.99	1.77	1.80	1.76	2.03

TABLE II

FINAL CONFIGURATION FOR THE 18 STRESSORS IN 4 DIMENSIONS

STRESSOR		DIM. 1	DIM. 2	DIM. 3	DIM. 4
1.	IP	0.611	0.788	-0.238	-0.258
2.	EE	0.453	0.507	-0.162	-0.608
3.	UH	-0.655	0.610	-0.243	0.429
4.	UC	-0.649	0.702	-0.248	0.307
5.	NO	-0.864	0.036	-0.322	0.252
6.	FC	-1.077	-0.331	-0.192	-0.213
7.	ED	-0.761	-0.432	-0.072	-0.313
8.	WD	0.734	-0.008	-0.351	-0.063
9.	NF	-0.107	0.068	1.026	-0.103
10.	BM	0.544	0.412	0.147	0.367
11.	GJ	0.720	-0.720	-0.428	0.113
12.	OO	0.199	0.354	0.843	0.101
13.	FA	0.530	0.828	-0.246	-0.003
14.	CP	0.560	-8.821	-0.314	-0.062
15.	MT	0.162	-0.332	0.756	-0.371
16.	RD	0.634	-0.795	-0.188	0.177
17.	HD	-0.942	-0.264	-0.131	-0.477
18.	CH	-0.092	-0.603	0.362	0.723

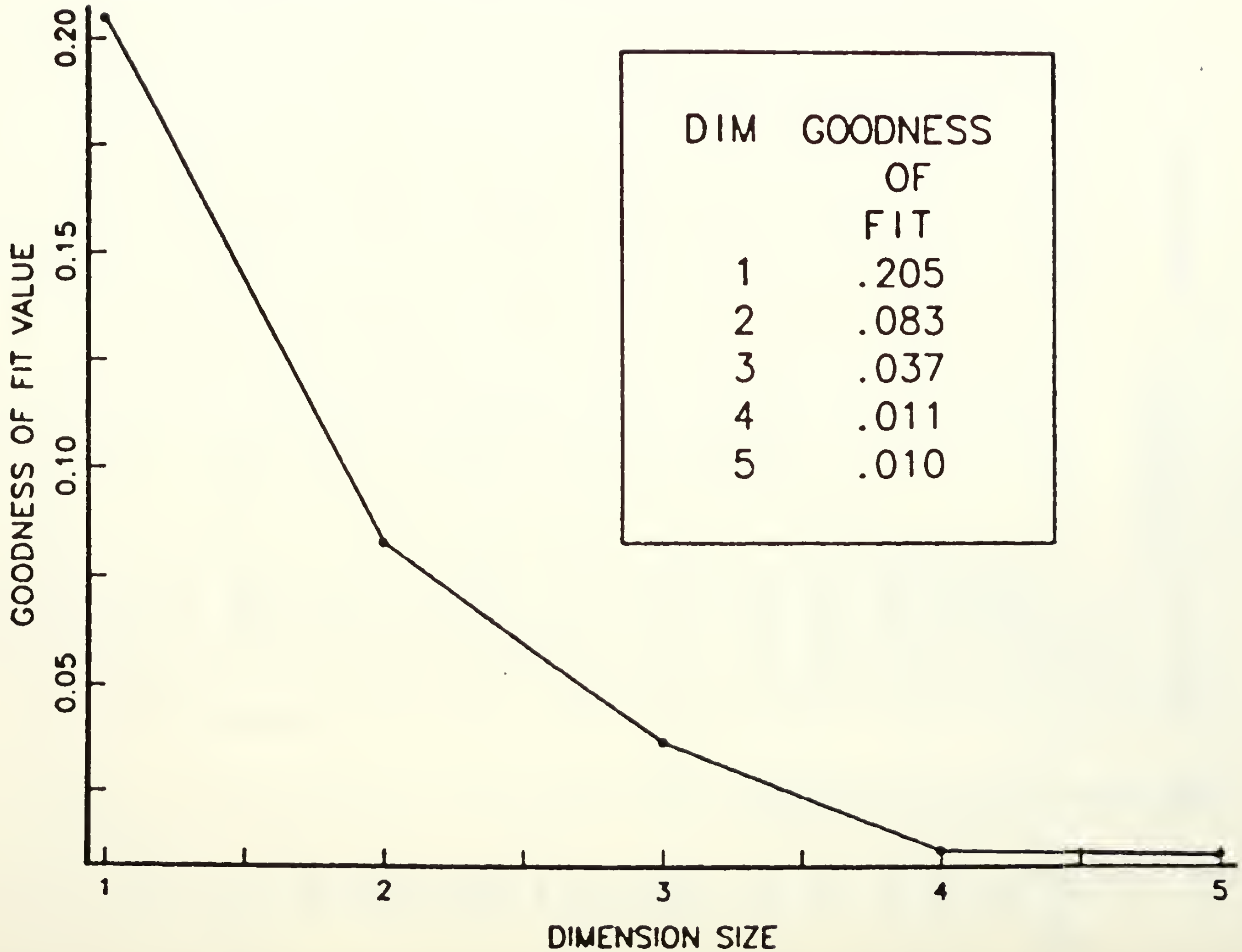

Figure 3.1. Goodness of Fit vs. Dimension Plot

Visually interpreting the results of the multidimensional scaling requires some knowledge of the characteristics associated with the stressors involved. The underlying features are represented as the dimensional axes in the plots of the solution. From these plots the interpretation centers on finding possibly perpendicular lines in the space such that the stressors at opposite extremes of a line differ from each other in some easily describable way [Ref. 13:p. 31].

Beginning with dimension one, the interpretation is that of the stressors which are environment dependent. One extreme of the dimension contains the stressors flight characteristics, helicopter design, equipment design, noise, uncomfortable heat, and uncomfortable cold. Each of these stressors are predominantly flight oriented. How the helicopter handles in flight, the noise generated by the helicopter, how the helicopter and the personal equipment were designed, and the thermal environment while flying are included here. At the other end of this dimension are those stressors that are associated with the environment the pilot lives in while away from flying. Stressors contained here are exercise environment, fatigue, command pressure, irregular patterns of sleep and eating, role demands, ground job and watches/duties. These range from non-flying work requirements such as the pilot's ground job and military

duties, to variable flight schedules and confined exercise areas. Therefore, the stressors on either extreme of this dimension represent the environment that the helicopter pilot is operating in, either in the air or on the ground.

Dimension two is interpreted as how often a stressor occurs. One end of the dimension consists of those stressors which are around the pilot constantly. These include command pressure, role demands, ground job, copilot characteristics, equipment design, flight characteristics, mission types, and helicopter design. Stressors in this group are present on a consistent basis. The pilot can count on having some type of command pressure to perform up to standards at all times. Helicopter and equipment design remain constant throughout each flight unless some design change is accomplished. A pilot will always have a ground job to perform while not in the cockpit. The other extreme of the dimension involves those stressors that are variable in nature. Contained here are the stressors that show up only occasionally. Included are operator overload, boredom/ monotony, exercise enviroment, uncomfortable heat and cold, fatigue, and irregular patterns of sleep and eating. Helicopter pilots go through periods where long and difficult flights occur consistently. Then, as quickly as they began, the number of flights decrease and periods of less demanding flying appear. With these rising and falling

periods of high tempo flying come the stresses associated with the changes. Overloading the pilot with tasks, fatigue from long work hours, and irregular sleeping and eating patterns are related to this type of operational flying. The different environmental temperatures that the helicopter operates in change constantly. Thus, dimension two relates to whether the stressor occurs on a constant or variable basis.

How a stressor is related to the actual mission of the flight is the interpretation of dimension three. At one extreme of the dimension are those stressors not directly involved with the type of mission being flown by the helicopter pilot. These include stressors such as command pressure, ground job, watches/duties, noise, equipment design, and flight characteristics. They do not present a direct problem to the pilot when he is in the middle of carrying out a mission. Stressors like mission type, night flying, operator overload, and copilot characteristics affect him as he is performing the mission. Night flying tends to focus the attention of the pilot dramatically while accomplishing his mission. A capable copilot helps relieve a large amount of stress during a mission, while the opposite increases the workload required. Dimension three relates how a stressor is involved in the actual performance of a mission by the helicopter pilot.

The fourth dimension is interpreted as being whether the stressor emanates from the helicopter itself or by the mental or physical demands placed on the pilot. Stressors produced by the helicopter are the helicopter design, flight characteristics, equipment design, and noise. These exist primarily in the helicopter community, although equipment design is universally associated with all types of aircraft. Long periods of helicopter flight is primarily stressful due to characteristics such as airframe vibration and noise. Mental demands place the pilot in stressful situations unlike those brought on by the helicopter. These stressors are carried on to the helicopter by the pilot or are placed on him by outside forces. Pressure to get the job done in a certain time frame or manner and being pressured into performing too many tasks are stressors at this extreme of the dimension. Also included are role demands, boredom/ monotony, fatigue, and ground job. Pilots have to be capable of putting all problems not directly associated with the flying of the aircraft behind him while flying. This dimension describes the type of stressors the pilot faces, mental and physical stressors or helicopter generated stressors.

Interpreting the dimensions of any multidimensional scaling output is very subjective. What one analyst determines to be an interpretation may not be the same as that of

another analyst viewing the same output. A good association with the topic being analyzed is an absolute necessity which should not be ignored.

C. RANKING ANALYSIS

Results of the ranking of the stressors by the helicopter pilots are discussed in this section. Detailed rankings of individual pilots are given in Appendix H. Final rankings according to performance factor are shown in Table III. As can be observed from the ranking results, the high stress stimuli among the different performance aspects have some similar elements. Fatigue is the highest stress producer of the set of stressors. Two other stressors, irregular patterns of sleeping and eating and operator overload, were consistently ranked in the top four. Rankings of the central group of stressors were more variable compared to those of the top and bottom. The least stressful elements were predominantly the stressors of role demands and ground job. Average rankings for each stressor are given in Appendix H.

The Friedman Test [Ref. 14:pp. 299-300] was performed on the ranking data to test whether or not each ranking of the set of stressors within a block were equally likely. The alternative hypothesis stated that at least one of the stressors tended to yield larger observed values than at least one other stressor. The test statistic for the

TABLE III

OVERALL STRESSOR RANKS

PERFORMANCE ASPECT

RANK	OVERALL	THINKING	ALERTNESS	EYE-HAND COORD.
1	FATIGUE	FATIGUE	FATIGUE	FATIGUE
2	NIGHT FLYING	OPERATOR OVERLOAD	IRREGULAR SLEEP, AND EATING	IRREGULAR SLEEP AND EATING
3	OPERATOR OVERLOAD	IRREGULAR SLEEP AND EATING	BOREDOM/ MONOTONY	OPERATOR OVERLOAD
4	IRREGULAR SLEEP AND EATING	NIGHT FLYING	UNCOMFORT. HEAT	HELICOPTER DESIGN
5	COPILOT	UNCOMFORT. HEAT	UNCOMFORT. COLD	NIGHT FLYING
6	WATCHES/ DUTIES	NOISE	OPERATOR OVERLOAD	UNCOMFORT. HEAT
7	UNCOMFORT. HEAT	BOREDOM/ MONOTONY	WATCHES/ DUTIES	FLIGHT CHARACTER.
8	UNCOMFORT. COLD	COPILOT	COPILOT	EQUIPMENT DESIGN
9	MISSION TYPE	UNCOMFORT COLD	EXERCISE ENVIRON.	UNCOMFORT. COLD
10	COMMAND PRESSURE	COMMAND PRESSURE	NOISE	BOREDOM/ MONOTONY
11	NOISE	WATCHES/ DUTIES	NIGHT FLYING	EXERCISE ENVIRON.
12	BOREDOM/ MONOTONY	MISSION TYPE	FLIGHT CHARACTER.	WATCHES/ DUTIES
13	EXERCISE ENVIRON.	EXERCISE ENVIRON.	EQUIPMENT DESIGN	NOISE

TABLE III (CONTINUED)

14	EQUIPMENT DESIGN	FLIGHT CHARACTER.	HELICOPTER DESIGN	MISSION TYPE
15	FLIGHT CHARACTER.	HELICOPTER DESIGN	MISSION TYPE	COPILOT
16.	HELICOPTER DESIGN	EQUIPMENT DESIGN	GROUND JOB	COMMAND PRESSURER
17.	GROUND JOB	GROUND JOB	COMMAND PRESSURE	GROUND JOB
18.	ROLE DEMANDS	ROLE DEMANDS	ROLE DEMANDS	ROLE DEMANDS

Friedman Test is the value of T_2. At the .05 level, the rejection criteria for this null hypothesis is if T_2 exceeds the .95 quantile of the F distribution. All four rankings were found to be significant at the .05 level resulting in rejection of the null hypothesis with greater than .95 confidence. Results are shown in Table IV.

Next, Kendall's Coefficient of Concordance [Ref. 14: p. 305] was used in order to determine the extent of the agreement among the rankings. A null hypothesis that there is no agreement among the rankings is used. The statistic is based on the value of W. Perfect agreement in the rankings result in a value of W equal to 1.0, while perfect disagreement is indicated by a value of W equal to 0. With b rankings of a set of k objects, this test compares the statistic $b(k-1)W$ with quantities of the chi-square distribution, k-1 degrees of freedom. All rankings were found to be significant at the .05 level, resulting in rejection of the null hypothesis with greater than .95 confidence. Results of this test are displayed in Table V. Therefore, these tests indicate that the helicopter pilots were not performing the rankings in a totally random manner and were ranking the stressors in a consistent way for each performance aspect.

Contained in Appendix I are graphical plots of how each type of helicopter pilot varied in his ranking of the

TABLE IV

FREIDMAN TEST RESULTS OF RANKING DATA

RANKING CRITERION	FREIDMAN TEST STATISTIC	REJECTION LEVEL
OVERALL	11.27	<.001
THINKING/DECISION MAKING	11.48	<.001
ALERTNESS	22.29	<.001
EYE-HAND COORDINATION	20.09	<.001

TABLE V

SIGNIFICANCE OF AGREEMENT IN RANKING DATA

RANKING CRITERION	KENDALL'S W	X (CHI-SQUARE) BASED ON W	REJECTION LEVEL
OVERALL	.3532	162.12	<.001
THINKING/ DECISION MAKING	.3063	140.59	<.001
ALERTNESS	.4442	203.89	<.001
EYE-HAND COORDINATION	.4751	218.07	<.001

stressors. These plots show the percentage of rankings at or above the overall median value assigned to each stressor. Pilots flying the SH-2 consistently ranked the stressors exercise environment and ground job higher than they were ranked by the other helicopter pilots. This could be due to the fact that SH-2 helicopters operate off of smaller ships and therefore the space available for exercise is far more limited. As for the ground job, a possible explanation is that the SH-2 usually deploys with very few pilots and the workload, while not flying, may be greater than that experienced by others. The SH-3 pilots ranked night flying as being higher in stress than it was perceived to be by the other pilots. The main reason for this was that the SH-3 operates in the low altitude, over water, and night flying arena as part of their mission requirements. As for the CH-46, uncomfortable heat and cold and boredom/monotony were the stressors that separated them from the other helicopter types. The mission of the CH-46 is one that consists of periods of high operational tempo followed by long lessor active periods.

IV. DISCUSSION

A. REVIEW

The goals of this study were to identify stressors which may affect the performance of Naval helicopter pilots, estimate those stressful conditions which are perceived as having the greatest impact on the performance of the pilot, and to determine a pattern, if any, from the collected data. Data was collected using a survey completed by Naval helicopter pilots attending the Naval Postgraduate School in Monterey, California. Ranking, according to performance aspects, and unconditional sorting of the given stressors were the methods used to gather the needed information.

Multidimensional scaling was the primary method utilized in analyzing the patterns that the pilots may have used in grouping the stressors. A four dimensional interpretation was determined to be the most appropriate based on an associated goodness of fit value of .011. Goodness of fit values less than .025 indicate a better than excellent fit. The interpretation of dimension one was that of stressors which are environment dependent. Dimension two showed how often a stressor occurred. Dimension three related as to how a stressor was involved with the actual performance of a mission. Finally, dimension four was interpreted as to

whether a stressor was generated by the helicopter or by other means.

Analysis of the ranking data brought forth some common perceptions of the stressors when compared to the different performance aspects. In general, fatigue, irregular patterns of sleep and eating, and operator overload were those stressors consistently ranked as being the most stressful. As for the least stressful among the given stressors, ground job and role demands were listed as to fitting that category. A comparison between the different helicopter types, the SH-2, SH-3, and CH-46, and their responses for the ranking data was also made. Pilots flying the SH-2 ranked the stressors exercise environment and ground job consistently higher for all performance aspects than the other helicopter types. For the SH-3, night flying was ranked higher compared to the rankings of the SH-2 and CH-46. The CH-46 pilots ranked uncomfortable heat and cold and boredom/monotony as being more stress producing than indicated by the rankings provided from the other helicopter types.

What do these results indicate about the manner in which a helicopter pilot views the stresses associated with his job? It appears that the pilots consider stressors that are linked with fatigue as being among the most stressful. Overloading the operator is such a common occurrence, when

flying Naval helicopters, that the necessity for a copilot is of utmost importance. Not only does the additional pilot help with the actual flying of the aircraft, but also with the administrative and tactical duties as well. There are times when one of these activities alone are an overload on the pilot. Emergency situations require total mental concentration and physical ability in handling the aircraft. Additional sources of distraction to the pilot decrease this ability. A tactical mission many times requires that the aircraft be flown in close proximity to the water. Overloading a pilot here could be disastrous. Couple this with the fact that often this flight occurs in low visibility conditions. Helicopters have always been designed with the capability of being able to perform a variety of tasks. This capability becomes a fatiguing factor when, what started out as one mission, evolves into a series of different missions. Each of these additional missions have their own set of requirements for which the pilot must be prepared. These flights can last for long periods of time resulting in fatigue of those involved.

Part of being a Naval helicopter pilot involves the possibility of flying during all hours of the day and on an irregular schedule. Flight schedules, by nature, vary in the number of flights required as well as in the time periods which the flights occur. Pilots must remain

flexible enough to accommodate this variability. Normal daily functions such as eating and sleeping also become variable. This tends to be stressful when not accompanied by a recovery period where the body returns to a normal operating tempo. Even though he may be capable of sleeping for the desired length of time, he may not be able to do this. Sleeping on board ship, where there is constant activity and noise, can be a difficult act to perform.

These types of stressors were singled out by the pilots as being the most stressful, but a point to understand is that these stressors act in conjunction with many others. Operator overload, for instance, does not occur by itself without any other stressors existing. With combinations of stressors come an increase in the total amount of stress. This is the normal condition a helicopter pilot faces. The stressors which were rated the highest seem to indicate that the pilots consider them to directly affect how safely he can fly his aircraft. The occurrence of any one of these are important to him in that respect.

B. CONCLUSIONS

1) The technique of multidimensional scaling provided a means to explain how the helicopter pilots grouped the given stressors.

2) While a visual interpretation of the output was performed for this study, multiple linear regression analysis is an alternative method available when visual inspection fails to discover any patterns.

3) It should be emphasized that the interpretations, independent of the analytical method used, are still determined subjectively.

A major product of this study is an increase in awareness of the factors that cause stress among helicopter pilots. Once stressors are identified, means of combatting their effects can be attempted. Some stressors, such as fatigue and noise, are inherent in the atmosphere surrounding helicopter flight. Others, such as ground job and exercise environment, can be dealt with by the pilot in a more effective manner to reduce their effects. Techniques exist which can be applied to handle stress and are well documented.

Every pilot, whether he is a helicopter pilot or not, has the responsibility of ensuring he can perform effectively on every flight. Stress can reduce this effectiveness. Knowledge of potential stressors and the ability to manage them is essential to safe operation of his aircraft and of himself.

APPENDIX A

STRESSORS

IP. Irregular Patterns of Sleep and Meals

sleeping and eating at odd hours not normally accustomed to

EE. Exercise Environment

lack of exercise, reduced ability to exercise due to shipboard conditions

UH. Uncomfortable Heat

high temperature, humidity, air flow which cause pilot to be uncomfortably hot

UC. Uncomfortable Cold

low temperature, humidity, air flow which cause pilot to be uncomfortably cold

NO. Noise

acoustical noise in the helicopter cockpit

FC. Helicopter Flight Characteristics/Vibrations

helicopter motion characteristics, vibrations associated with the helicopter in flight

RD. Role Demand

living up to traditional navy pilot role, behavior expected of a person by virtue of his or her position in the organization

MT. Mission Type

the primary mission of the type of helicopter you fly, i.e., ASW, SAR, VERTREP

HD. Helicopter Cockpit, Controls, and Instrument Design

human factor design characteristics of the helicopter, i.e., cramped cockpit, lighting, uncomfortable seating

ED. Personal Equipment Design

ill designed flight equipment, i.e., wetsuits, helmets, etc.

WD. Watches, Duty, Alerts

effects of watches, duty of your flying effectiveness; alerts such as 5, 15, and 30 minute for SAR or hostile threat

NF. Night Flying

instrument flying, night type of flying, i.e., night landings, night SAR, or night missions

BM. Boredom/Monotony

effects of boring, monotonous shipboard or flying life

GJ. Ground Job

non-flying characteristics which might affect flying, i.e., reports due, division member problems, etc.

OO. Operator Overload

performing difficult tasks, or many tasks at the same time

FA. Fatigue

working long hours for long periods of time, burnout

CP. Command Pressure

pressure to get job done quickly, from within your command or from another source

CH. Characteristics of Person You are Flying With

characteristics which conflict with you, i.e., aircraft system and procedure knowledge, personality, flying ability, etc.

APPENDIX B

SURVEY INSTRUCTION SURVEY

HELICOPTER PILOT STRESS SURVEY

Definition of stress----a mentally or emotionally disruptive or disquieting influence

As part of my thesis I would like you to rank the stressors, given on the index cards, beginning with the most stressful and down to the least stressful. A ranking of '1' indicates the most stressful, while a ranking of '18' is the least stressful. For separate rankings will be required, one for each of the performance aspects listed on the survey form. Just write in the rank you have assigned in the space provided. Think carefully about each ranking.

Next I would like you to group the stressors so that all similar stressors are grouped together. There are no restrictions as to the number or size of the groups. Write down the stressors (using the letter designators) by group numbers in the space provided. Determine the entries in these groups by how, in your own mind, the stressors are similar to each other.

(i.e., group 1 -- IP,UA,UC,EE

group 2 -- PA,NO,WD

etc.)

Finally, fill out the background questions on the form.

Performance Aspect Definitions

Eye-hand coordination	-- Here I am looking for how the stressors affect your physical ability to fly the aircraft
Alertness/vigilance	-- How do the stressors affect your ability to stay alert and vigilant to the task at hand, i.e., dozing off, concentration, etc.
Thinking ability	-- Which stressors affect your ability to think about the correct tactic to use, the correct procedure to use, etc.
Overall	-- How do these stressors affect your overall ability to fly the helicopter

APPENDIX C

SURVEY ANSWER SHEET

STRESSOR RANKING

PERFORMANCE ASPECT

Rank	OVERALL	THINKING ABILITY	ALERTNESS/VIGILANCE	EYE-HAND COORDINATION
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				
16.				
17.				
18.				

STRESSOR GROUPING

Group 1 --

Group 2 --

Group 3 --

Group 4 --

Group 5 --

Group 6 --

Group 7 --

Group 8 --

Group 9 --

Group 10 --

Group 11 --

Group 12 --

Group 13 --

Group 14 --

Group 15 --

Group 16 --

Group 17 --

Group 18 --

BACKGROUND INFORMATION

1. Type of helicopter you fly --
2. Number of flight hours in that helicopter --
3. Any additional stressors that you would have added --

APPENDIX D

INPUT TO MULTIDIMENSIONAL SCALING PROGRAM KYST

```
DIMMAX=4,DIMMIN=1,R=2.0
REGRESSION=ASCENDING
COORDINATES=ROTATE
CARDS
PRINT=DISTANCES
ITERATIONS=75
TORSCA,PRE-ITERATIONS=3
LOWERHALFMATRIX
DIAGONAL=ABSENT
DATA
STRESS DATA
 18  1  1
(17F4.1)
1.17
1.87 1.88
1.87 1.88 0.58
2.00 1.93 1.28 1.28
2.03 2.03 1.81 1.81 1.15
2.03 1.99 1.85 1.85 1.72 1.21
1.37 1.64 2.00 2.00 2.00 2.03 1.99
1.95 1.92 1.90 1.90 1.98 1.87 1.92 1.95
1.46 1.69 1.84 1.84 2.00 2.03 1.91 1.61 1.86
1.94 1.90 2.03 2.03 2.03 2.03 1.96 1.34 2.03 1.95
```

1.84 1.95 1.93 1.93 1.95 1.98 1.98 1.88 1.25 1.58 2.03

0.93 1.40 1.78 1.78 2.00 2.03 2.03 1.52 1.92 1.42 1.99 1.71

1.99 1.92 2.03 2.03 2.03 2.03 1.96 1.54 2.03 1.90 0.99 2.03 1.99

1.99 1.85 2.03 2.03 1.93 1.89 1.91 1.92 1.28 1.86 1.91 1.63 1.99 1.77

2.03 1.95 2.03 2.03 2.03 2.03 2.03 1.96 1.58 2.03 1.90 1.16 2.03 2.03

0.82 1.85

2.03 2.03 1.86 1.86 1.67 1.21 0.75 2.03 1.94 1.99 1.99 1.98 2.03 1.99

1.89 1.99

2.03 1.98 1.95 1.98 1.83 1.89 1.98 1.98 1.74 1.91 1.83 1.82 1.99 1.77

1.80 1.76 2.03

COMPUTE

STOP

APPENDIX E

OUTPUT OF KYST FOR DIMENSIONS 1, 2, AND 3

TABLE VI

FINAL CONFIGURATION IN 1 DIMENSION

Stressor	Dim 1
1. IP	-0.625
2. EE	-0.645
3. UH	1.001
4. UC	1.037
5. NO	1.307
6. FC	1.567
7. ED	0.666
8. WD	-1.078
9. NF	0.260
10. BM	-0.410
11. GJ	-1.471
12. OO	-0.156
13. FA	-0.502
14. CP	-1.424
15. MT	0.010
16. RD	-1.344
17. HD	1.678
18. CH	0.130

TABLE VII

FINAL CONFIGURATION IN 2 DIMENSIONS

Stressor	Dim 1	Dim 2
1. IP	-0.696	-0.966
2. EE	-0.699	-0.665
3. UH	0.820	-0.579
4. UC	0.833	-0.610
5. NO	1.043	-0.054
6. FC	1.338	0.316
7. ED	0.742	0.691
8. WD	-0.933	-0.114
9. NF	0.096	0.030
10. BM	-0.252	-0.586
11. GJ	-1.114	0.528
12. OO	0.027	-0.273
13. FA	-0.286	-0.975
14. CP	-1.023	0.744
15. MT	-0.223	0.384
16. RD	-0.853	0.514
17. HD	1.243	0.514
18. CH	-0.061	0.773

TABLE VIII

FINAL CONFIGURATION IN 3 DIMENSIONS

Stressor	Dim 1	Dim 2	Dim 4
1. IP	-0.636	-0.800	0.363
2. EE	-0.377	-0.512	0.510
3. UH	0.815	-0.566	0.069
4. UC	0.818	-0.602	0.109
5. NO	1.088	-0.022	0.088
6. FC	1.089	0.401	0.088
7. ED	0.676	0.616	0.435
8. WD	-0.812	-0.036	-0.972
9. NF	0.161	-0.073	-0.972
10. BM	-0.463	-0.468	-0.139
11. GJ	-0.834	0.636	0.350
12. OO	-0.143	-0.534	-0.742
13. FA	-0.475	-0.895	0.182
14. CP	-0.910	0.730	0.154
15. MT	-0.256	0.166	-0.772
16. RD	-0.672	0.747	0.061
17. HD	0.843	0.423	0.518
18. CH	0.087	0.789	-0.602

APPENDIX F

PLOTS OF FOUR DIMENSIONAL SOLUTION

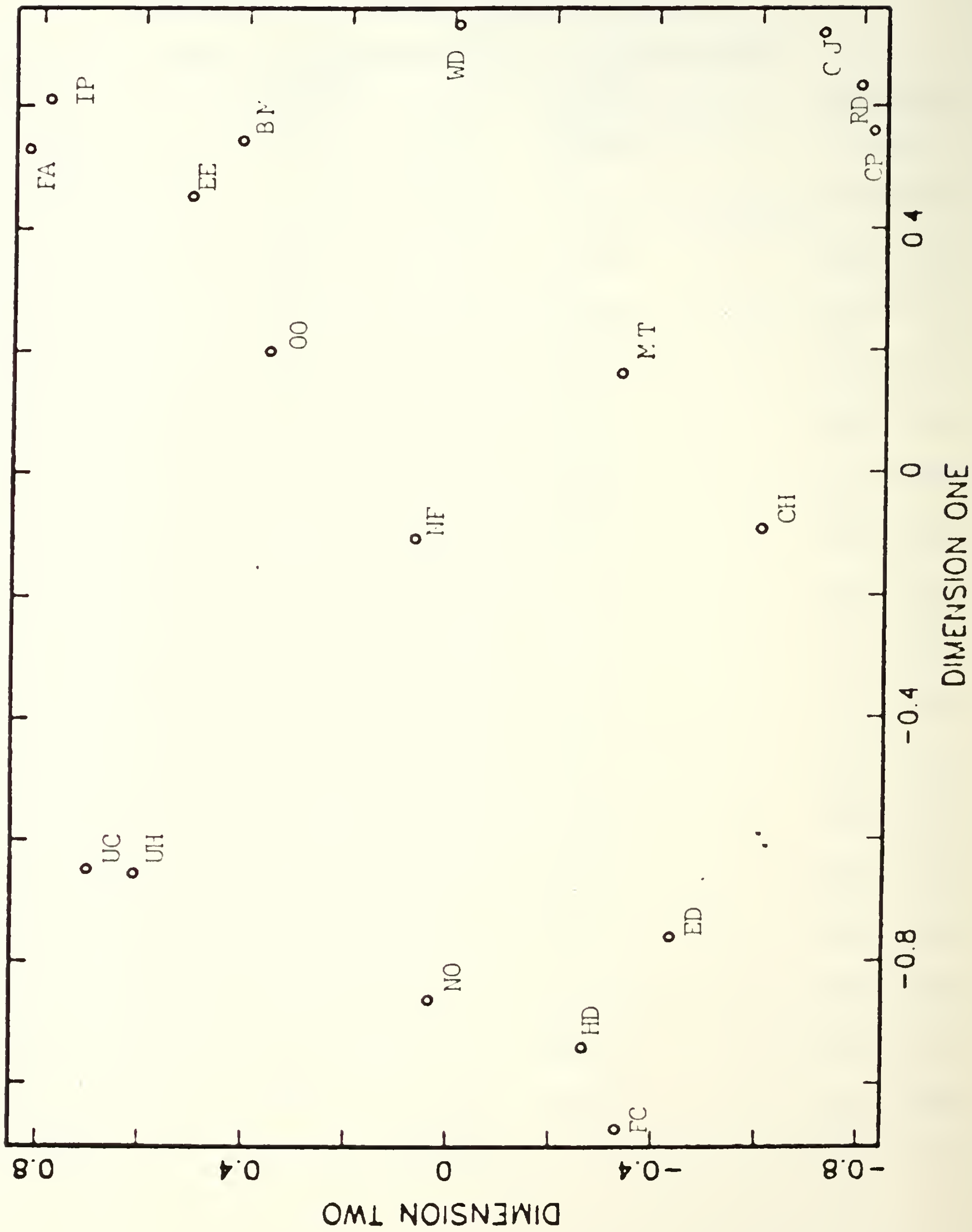

Figure F.1. Dimension One vs. Dimension Two

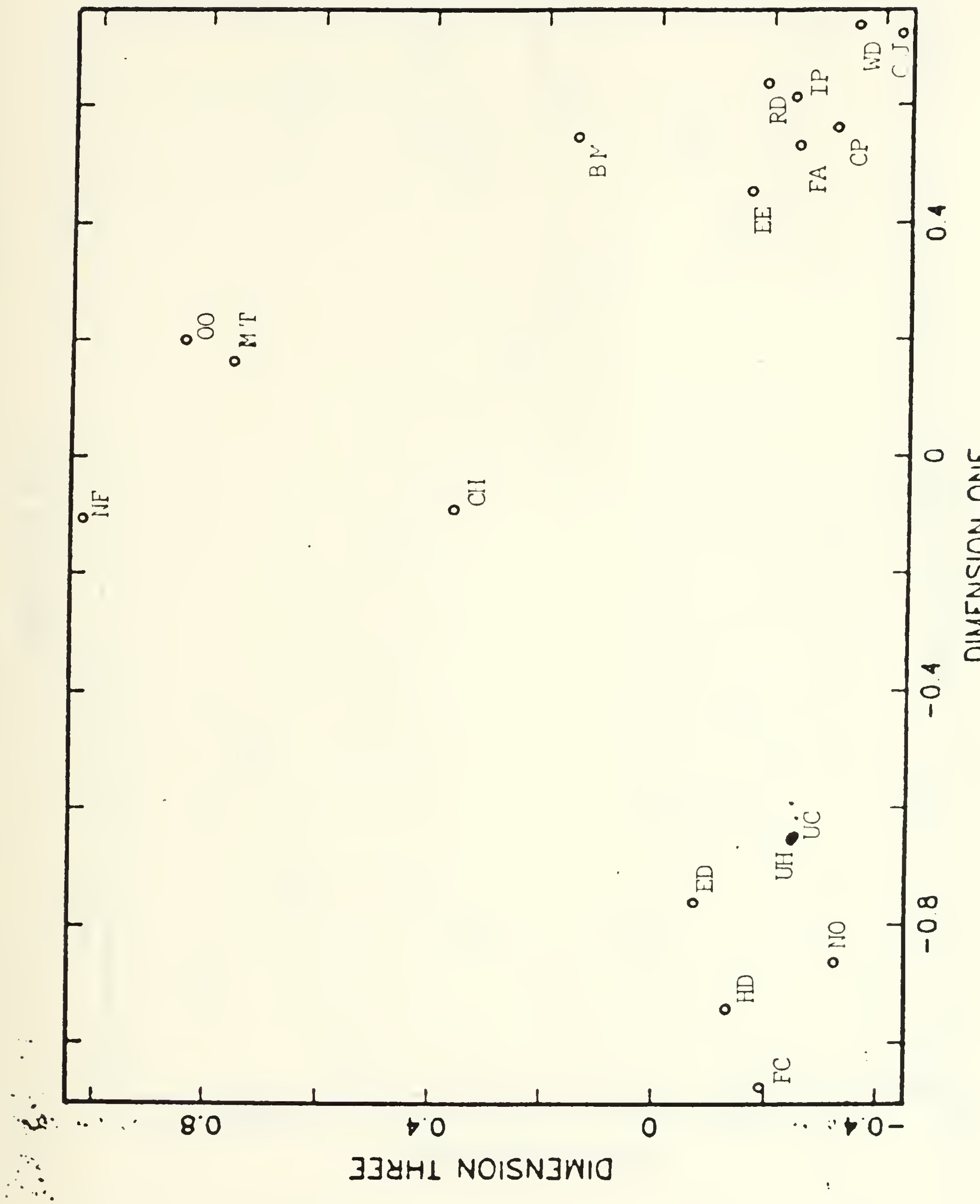

Figure F.2. Dimension One vs. Dimension Three

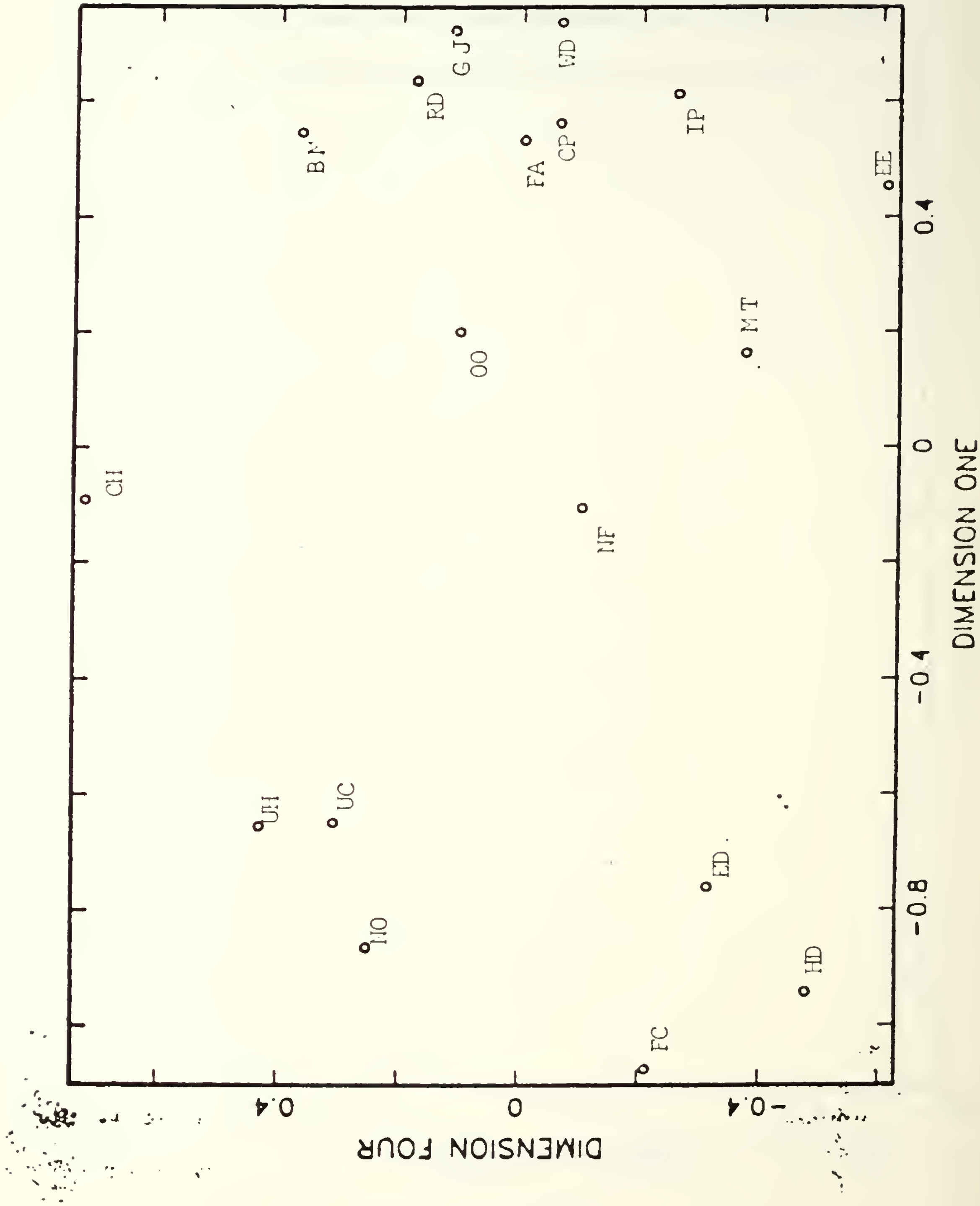

Figure F.3. Dimension One vs. Dimension Four

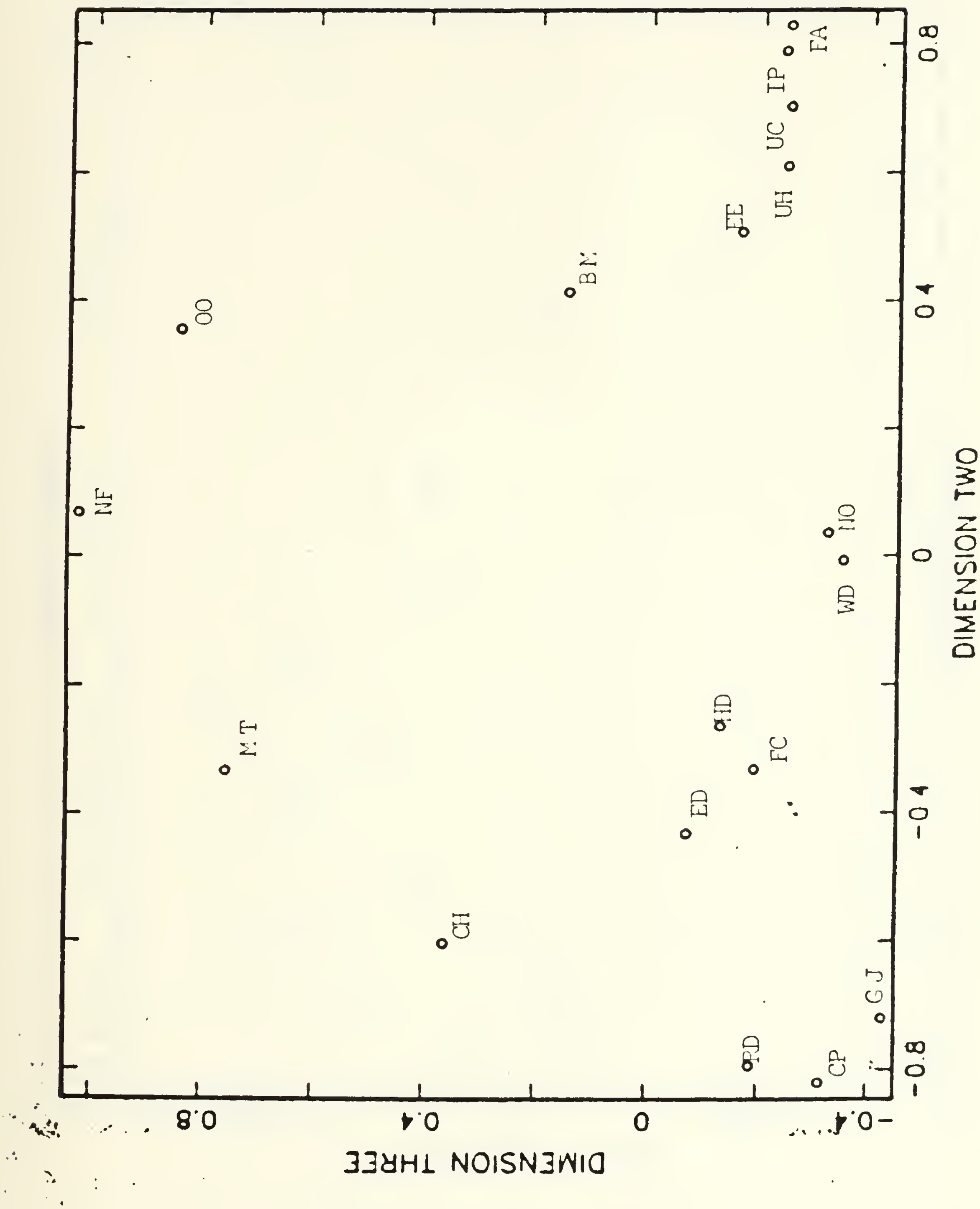

Figure F.4. Dimension Two vs. Dimension Three

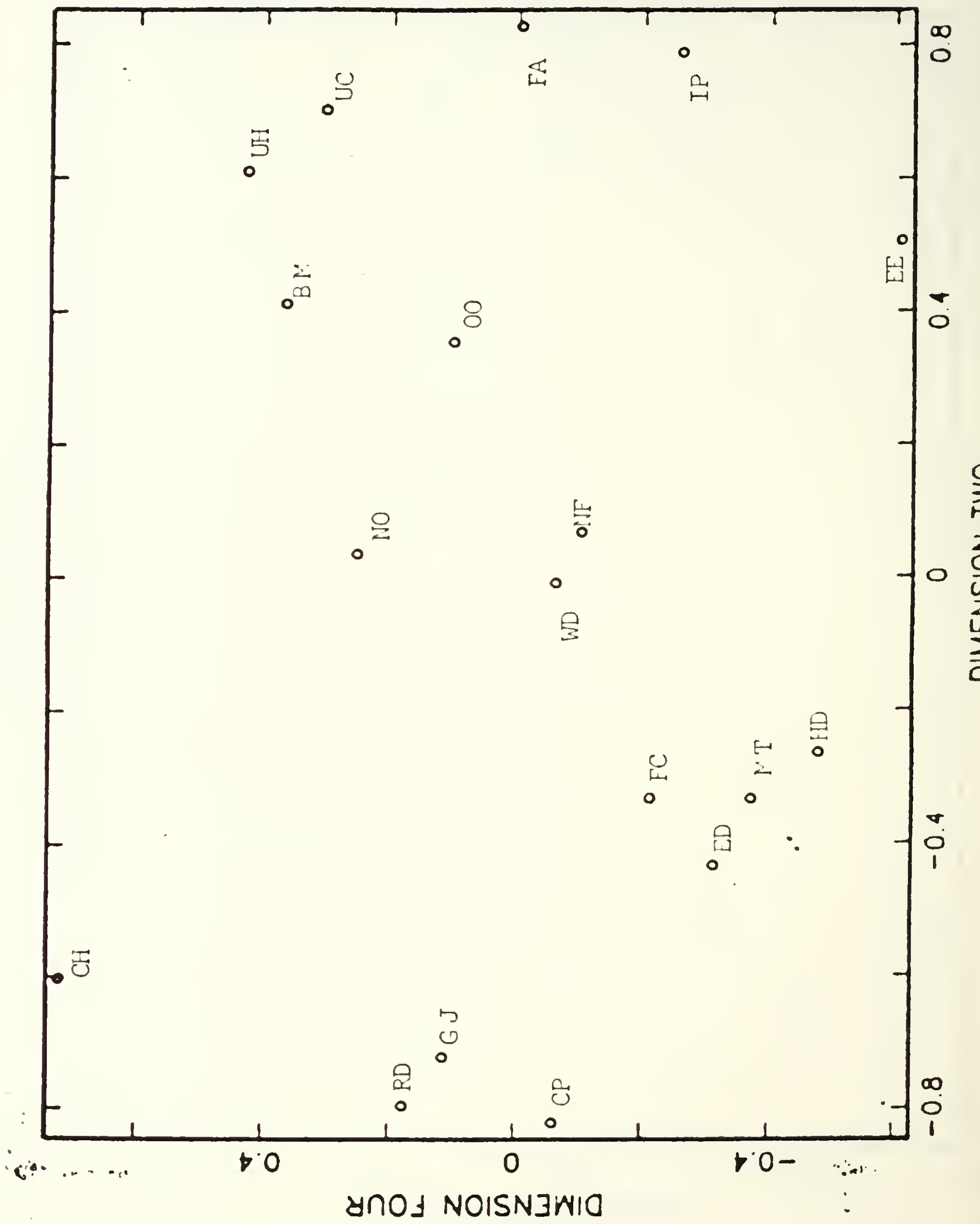

Figure F.5. Dimension Two vs. Dimension Four

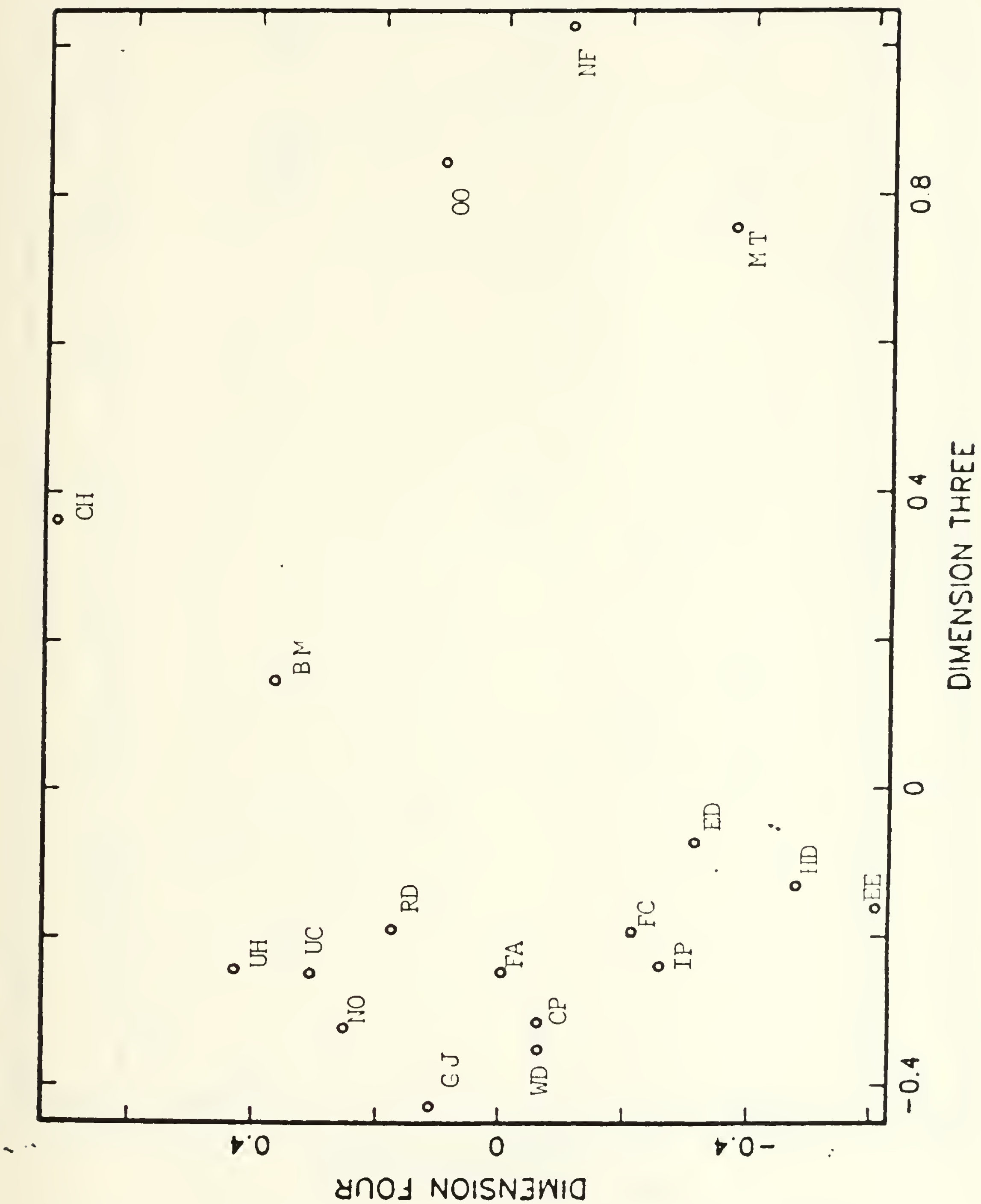

Figure F.6. Dimension Three vs. Dimension Four

APPENDIX G

PLOTS OF THREE DIMENSIONAL SOLUTION

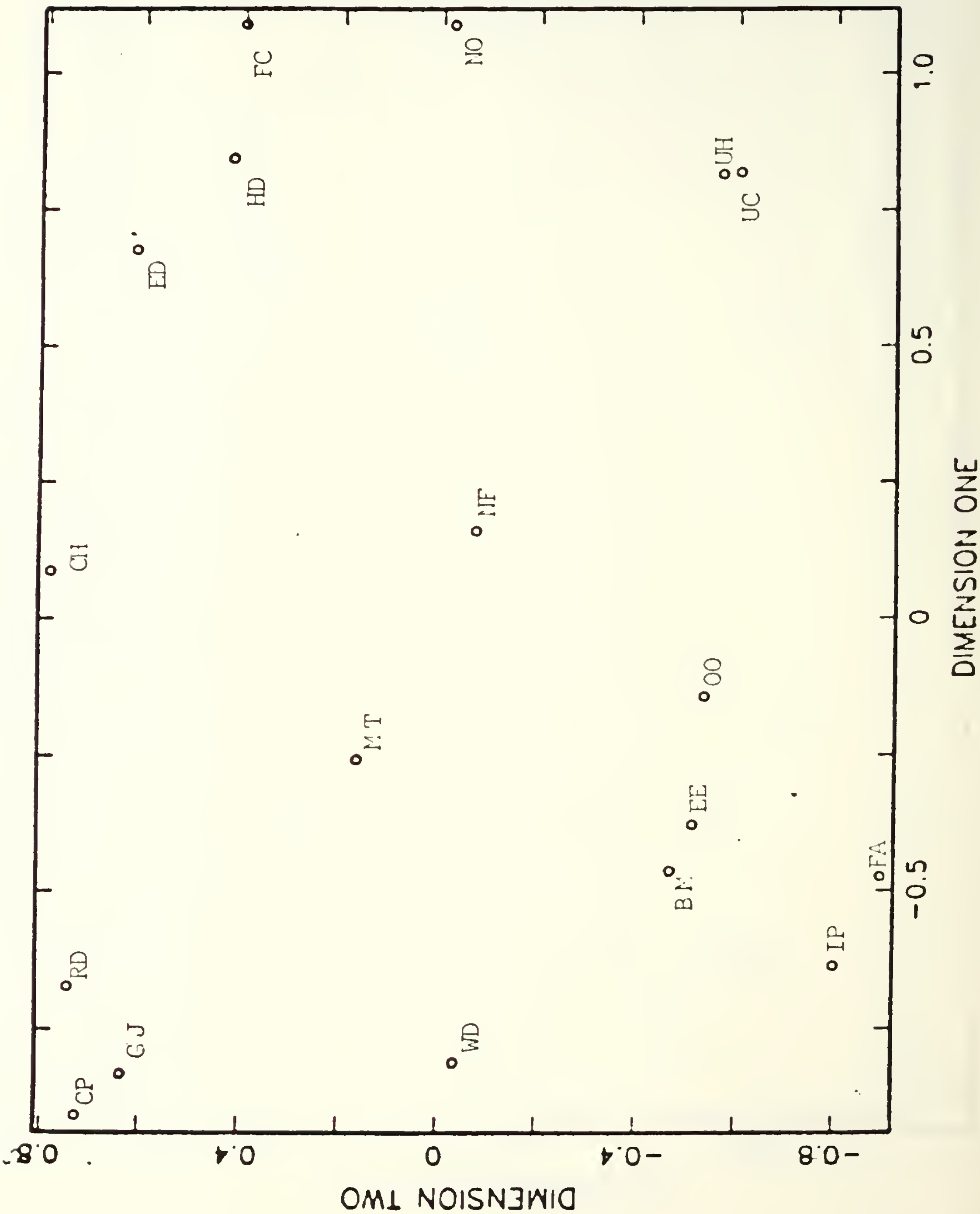

Figure G.1. Dimension One vs. Dimension Two

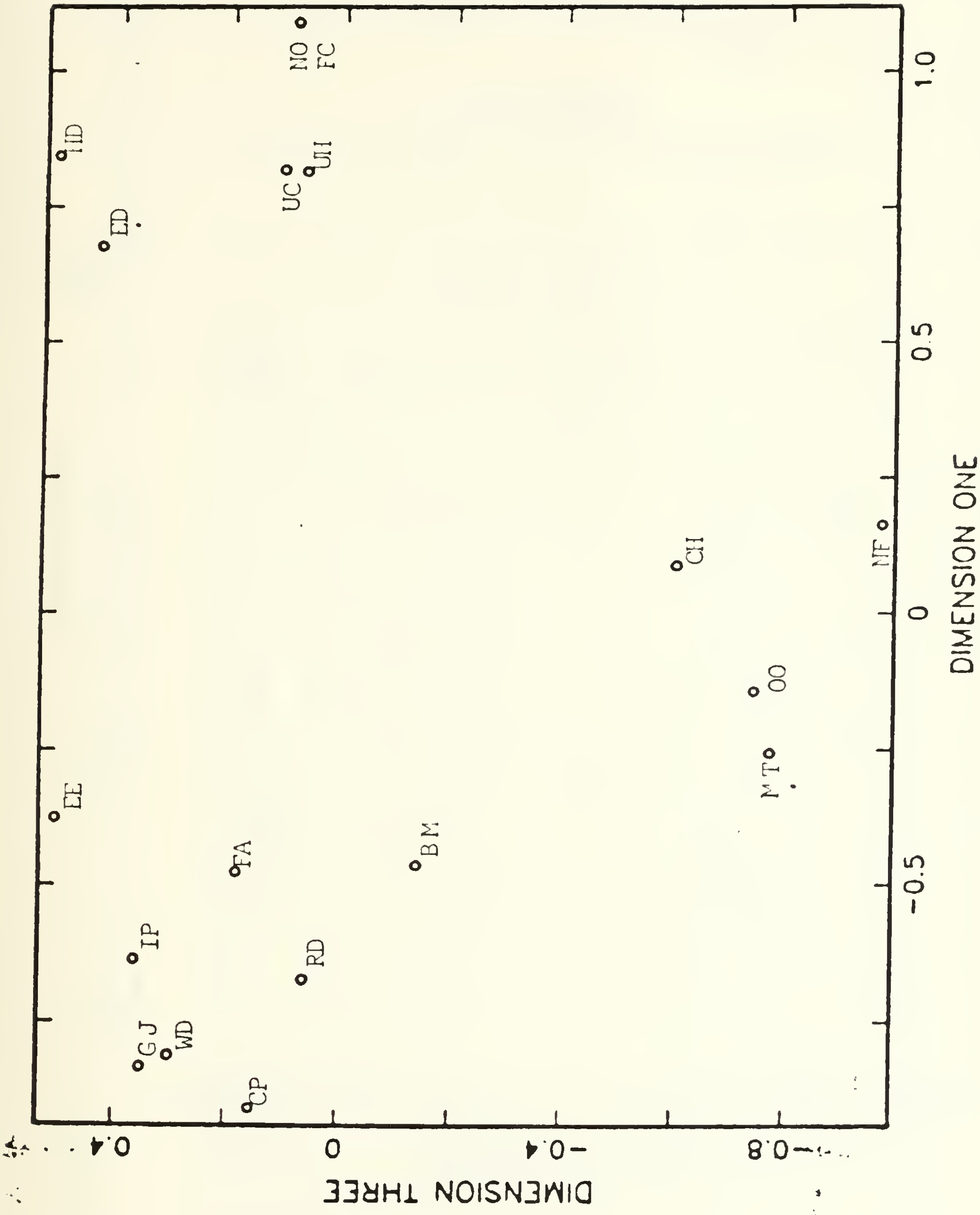

Figure G.2. Dimension One vs. Dimension Three

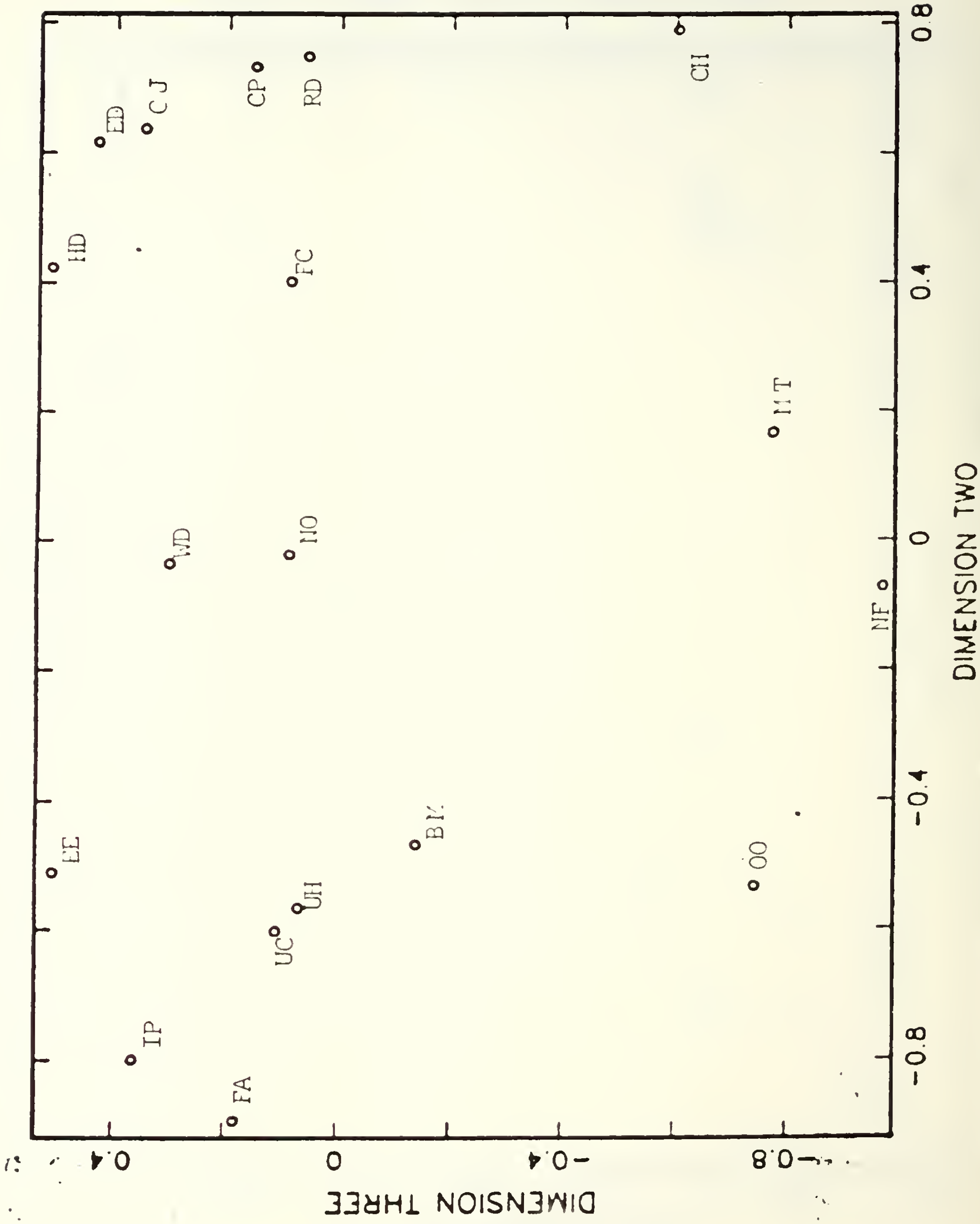

Figure G.3. Dimension Two vs. Dimension Three

APPENDIX H

STRESSOR RANKING DATA

FIRST RANKING

CRITERION: OVERALL ABILITY TO FLY HELICOPTER

Pilot Number	Stressor Given Rank Of:																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	FA	IP	00	ED	CH	HD	EE	UC	UH	NO	NF	FC	MT	GJ	WD	BM	RD	CP
2	GJ	CP	RD	CH	00	IP	FA	NF	MT	HD	BM	WD	EE	UH	ED	UC	FC	NO
3	FA	NF	IP	WD	EE	CP	00	BM	RD	CJ	HD	FC	CH	MT	NO	UH	UC	ED
4	FA	OO	GJ	NF	CP	WD	RD	UC	UH	NO	MT	IP	EE	CH	FC	HD	ED	BM
5	FA	00	WD	FC	HD	NF	ED	NO	UH	UC	CH	MT	CP	RD	IP	EE	GJ	BM
6	NF	FA	00	MT	IP	HD	ED	NO	WD	GJ	FC	CH	EE	BM	UC	UH	CP	RD
7	NF	MT	00	IP	FA	WD	CP	NO	CH	HD	ED	UC	RD	EE	UH	BM	FC	GJ
8	FA	NF	BM	00	UC	CH	WD	IP	UH	ED	RD	NO	MT	EE	HD	FC	CP	GJ
9	NF	FA	MT	00	FC	IP	BM	HD	UH	NO	ED	CH	GJ	WD	CP	EE	UC	RD
10	FA	NF	CH	00	WD	IP	BM	UH	ED	UC	FC	NO	HD	EE	GJ	CP	MT	RD
11	FA	NF	MT	00	WD	BM	IP	HD	CH	CP	GJ	FC	UH	NO	UC	RD	ED	EE
12	FA	IP	NF	00	WD	FC	CH	UC	UH	BM	GJ	EE	NO	ED	MT	HD	CP	RD
13	NF	FA	WD	FC	MT	EE	BM	NO	IP	UC	UH	ED	HD	CH	00	CP	RD	GJ
14	FA	NF	UH	CP	CH	00	MT	ED	GH	EE	UC	RD	NO	FC	IP	HD	WD	BM
15	NF	CH	00	CP	ED	FA	IP	WD	UC	UH	MT	BM	EE	HD	GJ	NO	FC	RD
16	NF	00	WD	GJ	CP	FA	IP	UC	UH	BM	FC	NO	HD	MT	CH	ED	RD	EE
17	UC	FA	NF	ED	UH	EE	IP	NO	BM	CH	HD	WD	MT	00	CP	FC	GJ	RD
18	FA	NF	00	IP	EE	NO	FC	CH	MT	BM	ED	WD	UH	CH	UC	CP	HD	RD
19	00	NF	CH	FC	HD	ED	UC	UH	CP	IP	FA	NO	MT	GH	WD	BM	EE	RD
20	IP	FA	00	WD	EE	RD	CP	NG	MT	GH	NO	UH	UC	CH	BM	FC	HD	ED
21	00	NF	WD	UH	FA	EE	CH	IP	GH	FC	HD	NO	UC	CP	ED	MT	BM	RD
22	FA	IP	UH	UC	GJ	CP	EE	RD	WD	00	BM	HD	ED	NF	MT	NO	CH	FC
23	NF	CH	FA	IP	00	CP	RD	EE	WD	ED	UC	UH	MT	NO	FC	HD	BM	GJ
24	UC	UH	FA	BM	NF	ED	EE	IP	NO	MT	HD	FC	00	CH	WD	CP	RD	GJ

25	NF	OO	MT	IP	FA	CP	CH	FC	HD	NO	ED	WD	GJ	BM	EE	UH	UN	RD
26	FA	BM	CH	NO	NF	OO	CP	UH	WD	UC	IP	FC	EE	MT	GH	RD	HD	ED
27	FA	BM	IP	UH	UC	OO	CP	NO	HD	FC	NF	EE	ED	MT	WD	CP	RD	GJ

SECOND RANKING

CRITERION: THINKING ABILITY

Pilot Number	Stressor Given Rank Of:																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	FA	IP	OO	CH	ED	EE	HD	UC	UH	NO	NF	FC	MT	GH	WD	BM	RD	CP
2	CH	RD	OO	CP	UH	NG	HD	BM	FA	IP	NO	FC	UC	ED	GJ	WD	MT	EE
3	FA	OO	MT	CP	IP	RD	EE	WD	BM	GJ	NG	CH	FC	HD	NO	UH	UC	ED
4	FA	OO	GH	CP	UH	UC	NO	NP	IP	EE	CH	MT	WD	RD	FC	HD	ED	BM
5	FA	OO	IP	MT	NF	NO	FC	CH	HD	CP	RD	UH	UC	WD	ED	EE	BM	GJ
6	OO	NF	MT	NO	FA	GJ	IP	BM	FC	WD	ED	HD	UC	UH	CP	EE	CH	RD
7	FA	WD	NO	IP	OO	MT	BM	NF	ED	UC	EE	HD	FC	CH	CP	UH	RD	GJ
8	FA	NF	OO	BM	CH	IP	WD	UC	UH	CP	ED	RD	NO	MT	EE	HD	RC	GJ
9	FA	NP	OO	BM	CH	IP	WD	UC	UH	CP	ED	RD	NO	MT	EE	HD	FC	GJ
10	FA	OO	WD	IP	BM	NO	CH	FC	UH	NF	ED	EE	HD	GH	UC	CP	MT	RD
11	FA	NF	MT	OO	WD	BM	IP	HD	CP	CH	GH	FC	UH	NO	UC	ED	RD	EE
12	FA	IP	UH	UC	BM	CH	WD	OO	NO	FC	NF	EE	GJ	ED	MT	HD	CP	RD
13	NF	FA	IP	BM	EE	WD	ED	FC	HD	CH	NO	MT	UC	UH	OO	CP	RD	GJ
14	FA	UH	CH	OO	MT	NF	CP	UC	BM	ED	EE	RD	NO	IP	HD	FC	GJ	WD
15	OO	FH	ED	CH	UC	FA	NO	GJ	CP	BM	UH	IP	FC	MT	HD	WD	EE	RD
16	BM	IP	FA	OO	CP	GH	WD	CH	UH	UC	NF	RD	ED	MT	HE	NO	FC	EE
17	UC	FA	OO	IP	NO	UH	EE	CP	MT	CH	HD	WD	BM	ED	NF	FC	GJ	RD
18	OO	MT	CH	BM	NF	NO	FC	EE	FA	IP	CH	HD	UH	ED	UC	RD	CP	WD
19	OO	CH	IP	FA	CP	BM	UC	UH	NO	ED	GJ	WD	EE	NF	FC	HD	MT	RD
20	FA	NO	CP	RD	UH	UC	IP	OO	WD	EE	MT	GH	BM	CH	NF	FC	HD	ED
21	OO	NF	HD	CH	MT	FA	RD	WD	EE	IP	FC	NO	CP	GJ	UC	UH	BM	ED
22	FA	IP	UH	UC	CP	GJ	WD	RD	EE	HD	ED	MT	NO	OO	BM	NF	CH	FC
23	FA	IP	OO	NF	UH	FC	CH	UC	NO	EE	ED	HD	WD	MT	RD	CP	BM	GJ
24	FA	UH	UC	BM	EE	IP	OO	NF	ED	MT	HD	FC	NO	CH	WD	CP	RD	GJ
25	FA	OO	GJ	IP	CP	NO	WD	UH	RD	NF	ED	UC	FC	HD	EE	BM	MT	CH
26	FA	BM	NO	FC	CP	UP	IP	WD	UC	EE	HD	ED	GJ	RD	CH	OO	MT	NF
27	FA	BM	IP	UH	UC	OO	CH	NO	HD	FC	NF	EE	ED	MT	WD	CP	RD	GH

THIRD RANKING

CRITERION: ALERTNESS/VIGILANCE

Pilot Number	Stressor Given Rank Of:																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	FA	IP	ED	EE	HD	UC	UH	CH	OO	NO	NF	FC	MT	GJ	WD	BM	RD	CP
2	FA	IP	ED	CH	NF	OO	BM	CP	FC	UC	UH	HD	RD	GH	WD	NO	EE	MT
3	FA	IP	EE	WD	BM	OO	CP	RD	GH	MT	NG	HD	FC	CH	NO	UH	UC	ED
4	FA	UH	IP	EE	BM	NO	UC	CH	MT	GH	CP	RD	WD	FC	HD	ED	OO	NF
5	FA	OO	BM	NO	FC	CH	CP	RD	UH	UC	ED	IP	WD	HD	NF	MT	GJ	EE
6	FA	IP	WD	NO	ED	BM	EE	FC	CH	UC	UH	GJ	CP	HD	MT	OO	NF	RD
7	FA	BM	NF	IP	ED	UH	WD	CH	MT	OO	NO	FC	HD	UC	EE	CP	RD	GJ
8	FA	BM	OO	NF	CH	WD	IP	UC	UH	ED	RD	NO	MT	EE	HD	FC	CP	GJ
9	FA	BM	IP	NF	OO	WD	UH	UC	GJ	CP	EE	HD	FC	NO	MT	CH	ED	RD
10	FA	WD	BM	IP	EE	FC	NO	OO	CH	GJ	UH	NF	UC	ED	HD	CP	MT	RD
11	FA	NF	MT	OO	WD	BM	IP	CH	UH	HD	CP	GJ	FC	NO	UC	RD	ED	EE
12	FA	IP	BM	WD	OO	UH	UC	GJ	EE	FC	NF	CH	NO	ED	MT	HD	CP	RD
13	NF	FA	BM	HD	ED	EE	IP	MT	FC	WD	UC	UH	NO	CH	OO	CP	RD	GJ
14	FA	UH	BM	EE	FC	IP	WD	OO	CH	UC	ED	NO	NF	RD	CP	MT	GJ	HD
15	BM	FA	IP	WD	ED	UC	GJ	OO	EE	HD	NG	FC	CH	UP	CP	NO	MT	RD
16	CH	FA	OO	NF	IP	BM	CP	GJ	WD	UC	UH	FC	NO	MT	HD	ED	RD	EE
17	FA	UC	BM	ED	UH	EE	MT	IP	CH	NO	OO	NF	WD	HD	CP	FC	GJ	RD
18	BM	IP	EE	FA	GJ	UH	NO	FC	ED	WD	UC	CH	MT	OO	NG	HD	RD	CP
19	FA	BM	IP	OO	CH	NF	MT	WO	UC	UH	NO	ED	FC	HD	CP	GJ	EE	RD
20	FA	IP	BM	UH	UC	CH	NF	NO	WD	OO	FC	MT	GH	CP	RD	EE	HD	ED
21	FA	UH	UC	NO	OO	IP	MT	BM	EE	CH	NF	FC	HD	GJ	WD	RD	CP	ED
22	FA	IP	UH	UC	OO	EE	CP	GJ	WD	RD	BM	HD	ED	NF	MT	NO	CH	FC
23	FA	OP	BM	MT	FC	UH	ED	UC	NO	EE	WD	HD	CP	RD	OO	CH	NF	GJ
24	FA	BM	UH	UC	IP	OO	EE	ED	HD	NO	FC	NF	MT	CH	WD	CP	RD	GJ
25	FA	IP	BM	UC	CH	EE	ED	FC	NO	HD	GJ	WD	CP	UH	RD	MT	OO	NF
26	FA	BM	NO	FC	CP	UH	IP	WD	UC	EE	HD	ED	GJ	RD	CH	OO	MT	NF
27	FA	BM	IP	UH	CH	OO	CH	NO	HD	FC	NF	EE	ED	MT	WD	CP	RD	GJ

FOURTH RANKING

CRITERION: EYE-HAND COORDINATION

Pilot Number	Stressor Given Rank Of:																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	FA	IP	OO	HD	ED	NO	EE	UC	UH	FC	CH	NF	MT	GJ	WD	BM	RD	CP
2	FA	IP	ED	NF	FC	HD	UH	UC	NO	MT	CH	RD	CP	BM	OO	GH	WD	EE
3	FA	EE	IP	WD	OO	BM	HD	FC	RD	GJ	CP	NF	MT	CH	NO	UH	UC	ED
4	OO	FA	HD	ED	FC	IP	EE	UC	UH	NO	BM	CH	MT	NF	CP	GJ	WD	RD
5	FA	FC	OO	HD	MT	NF	NO	ED	UH	UC	EE	WD	IP	CP	RD	GJ	CH	BM
6	FA	OP	OO	FC	HD	ED	WD	NF	MT	NO	EE	BM	CH	UC	UH	GJ	CP	RD
7	FA	IP	NF	OO	ED	BM	WD	MT	HD	FC	NO	CH	UH	UC	EE	CP	RD	GJ
8	FA	BM	NF	UC	UH	OO	CH	OP	WD	ED	RD	NO	MT	EE	HD	FC	CP	GJ
9	FA	HD	OO	IP	UH	UC	ED	BM	FC	EE	NF	NO	MT	WD	CH	GJ	CP	RD
10	NF	FA	WD	IP	BM	FC	EE	UC	ED	UH	OO	NO	CH	HD	GJ	CP	MT	RD
11	FA	NF	MT	OO	WD	BM	IP	FC	UH	CH	HD	ED	CP	GJ	NO	UC	RD	EE
12	FA	OP	UC	UH	WD	EE	OO	FC	NF	GJ	CH	BM	NO	ED	MT	HD	CP	RD
13	NF	HD	ED	FA	CH	OO	WD	EE	FC	NO	MT	UH	UC	OP	BM	CP	RD	GJ
14	FA	HD	UH	OO	NF	ED	FC	EE	OP	UC	BM	CH	NO	RD	CP	MT	GJ	WD
15	ED	HD	FA	BM	NF	OO	OP	WD	UC	EE	CP	UH	CH	FC	NO	MT	GJ	RD
16	FA	IP	HD	FC	NF	OO	BM	UC	UH	WD	GJ	CP	NO	CH	MT	ED	RD	EE
17	UC	ED	FA	HD	UH	OO	MT	CH	EE	OP	NF	NO	BM	WD	CP	FC	GJ	RD
18	IP	EE	FA	UH	OO	NF	BM	FC	NO	WD	ED	CH	GJ	UC	MT	HD	RD	CP
19	HD	ED	FC	NF	FA	BM	IP	UC	UH	NO	WD	OO	CH	MT	CP	GJ	EE	RD
20	FA	FC	IP	UH	UC	BM	NO	NF	EE	OO	WD	MT	GJ	CH	ED	HD	RD	CP
21	NF	HD	FC	MT	OO	FA	CH	OP	EE	UC	WD	ED	CP	RD	BM	NO	UH	GH
22	FA	IP	UH	UC	OO	ED	HD	CP	GJ	WD	RD	EE	ED	MT	NO	NF	CH	FC
23	FA	IP	HD	ED	EE	UH	BM	UC	FC	NO	WD	OO	NF	MT	CH	CP	RD	GJ
24	FA	BM	UH	UC	EE	OP	OO	ED	HD	NO	FC	NF	MT	CH	WD	CP	RD	GJ
25	FA	IP	MT	NF	HD	FC	ED	NO	UH	UC	OO	EE	CH	BM	WD	GJ	CP	RD
26	FA	OO	NO	UH	NF	BM	WD	FC	EE	UC	HD	IP	CP	ED	GJ	MT	RD	CT
27	FA	BM	IP	UH	UC	OO	CH	NO	HD	FC	NF	EE	ED	MT	WD	CP	RD	GJ

TABLE IX

AVERAGE RANKS OF STRESSORS

STRESSOR	OVERALL	THINKING	ALERTNESS	EYE-HAND
FA	2.74	2.37	1.26	1.74
EE	11.22	11.74	9.78	10.04
IP	6.26	5.56	4.11	5.22
CH	8.63	9.04	9.33	11.74
OO	5.00	4.59	8.67	6.22
WD	8.78	10.41	9.19	10.67
RD	14.33	13.70	15.22	16.11
CP	10.67	10.37	13.07	14.96
NF	3.33	8.26	10.48	7.11
GJ	12.52	12.33	13.04	15.29
NO	11.00	8.78	10.18	10.78
UH	8.96	8.52	7.63	7.41
UC	10.22	9.29	8.37	8.70
BM	11.04	8.89	4.18	8.78
FC	11.56	11.96	10.56	8.11
HD	11.67	12.00	12.48	7.00
ED	11.33	12.26	10.78	8.41
MT	10.44	10.93	12.74	11.70

APPENDIX I

PLOTS OF PILOT RANKING DATA

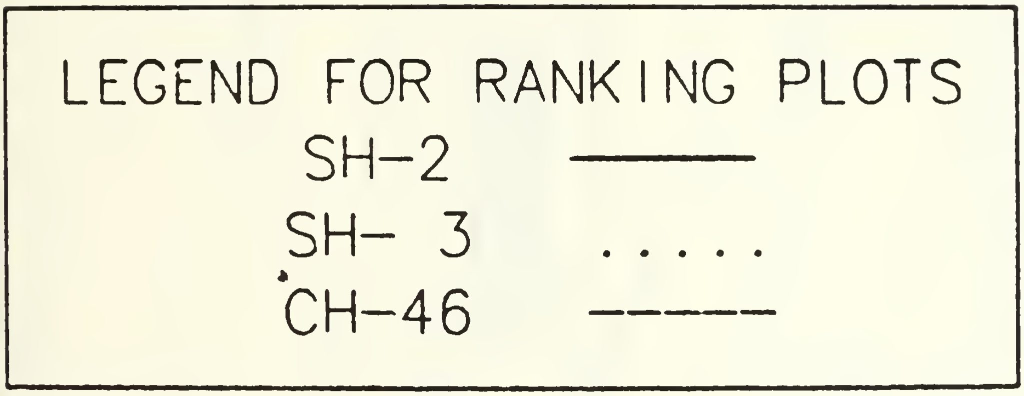

Figure I.1. Plot Legend for Pilot Ranking Data

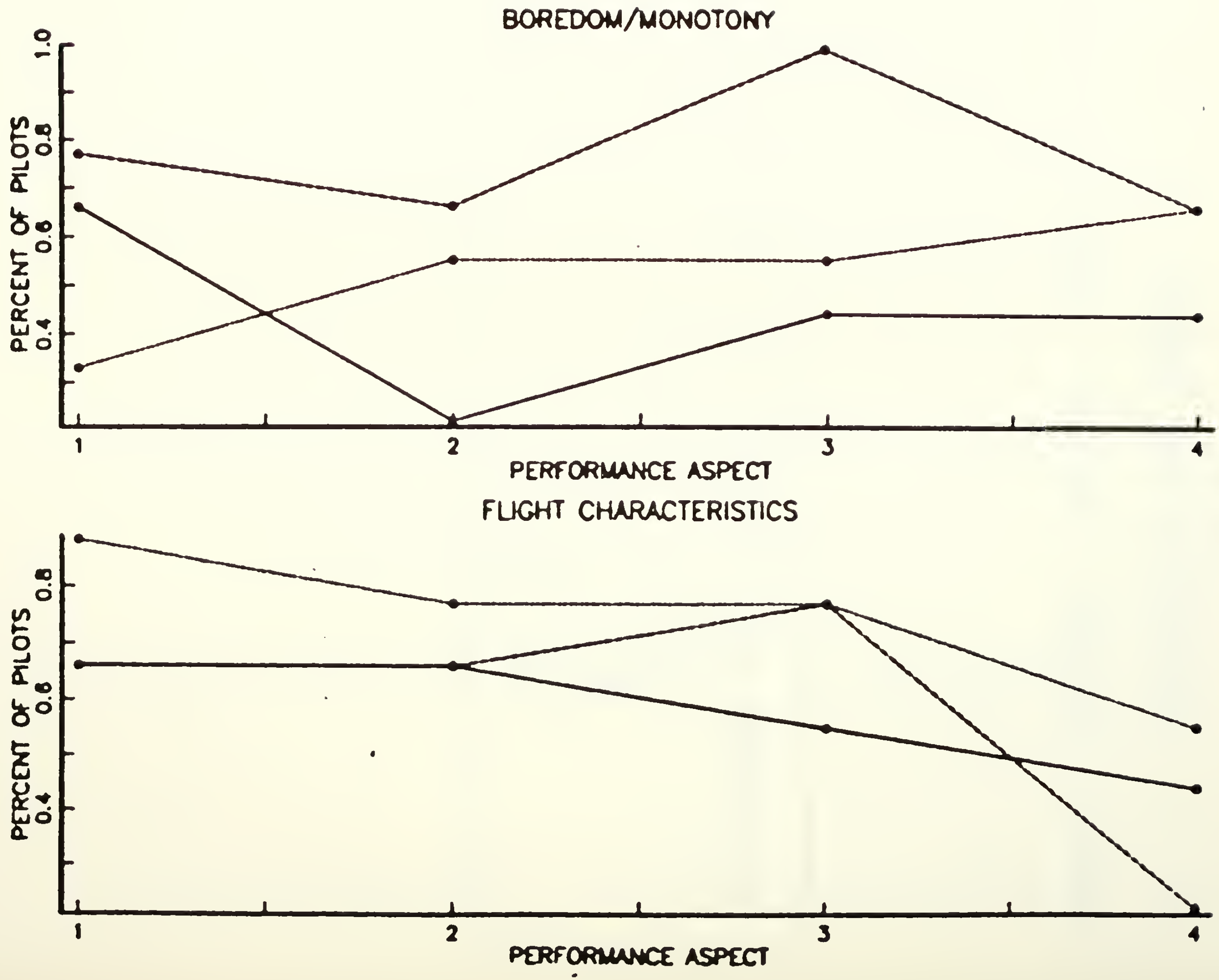

Figure I.2. Pilot Ranking Data

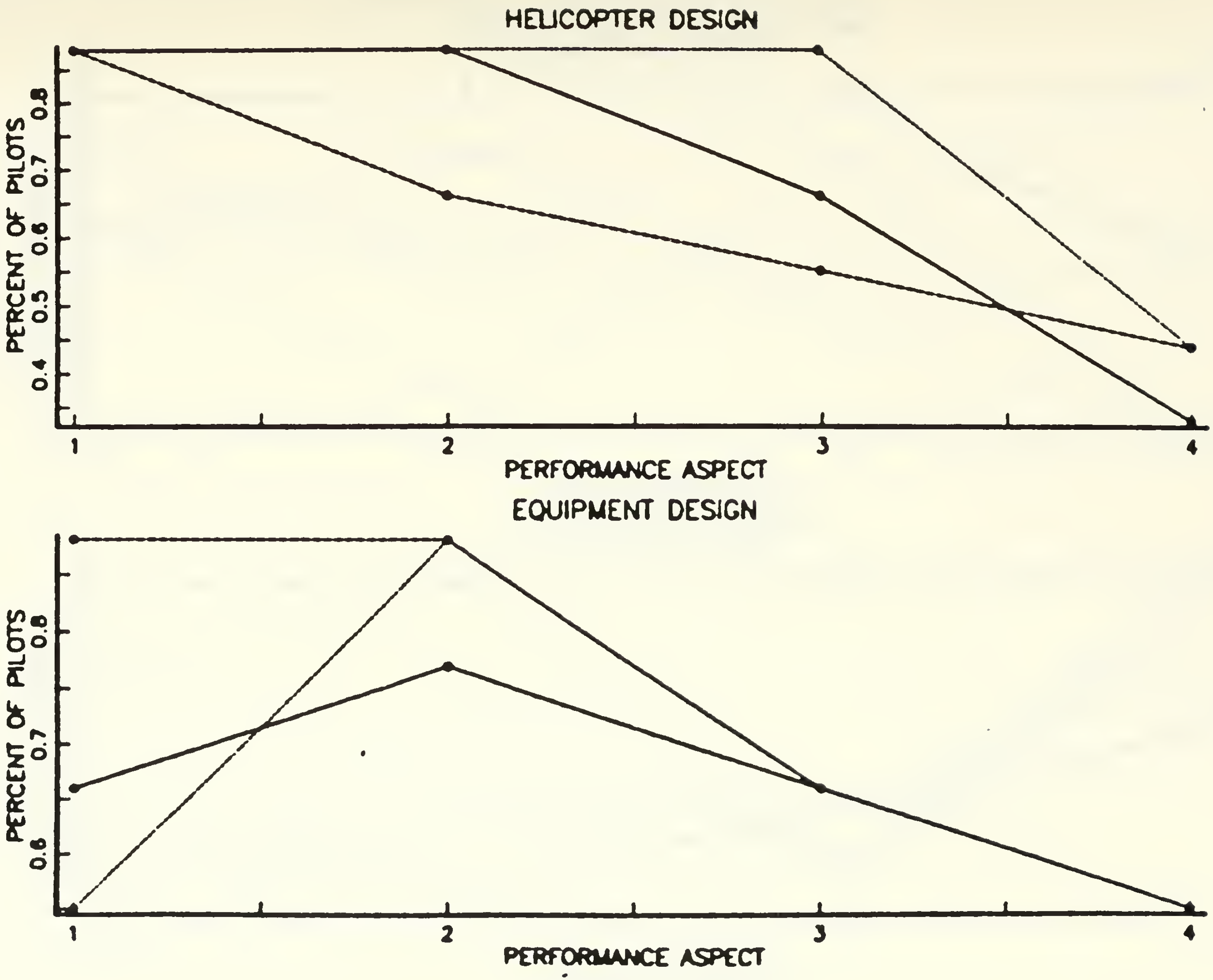

Figure I.3. Pilot Ranking Data

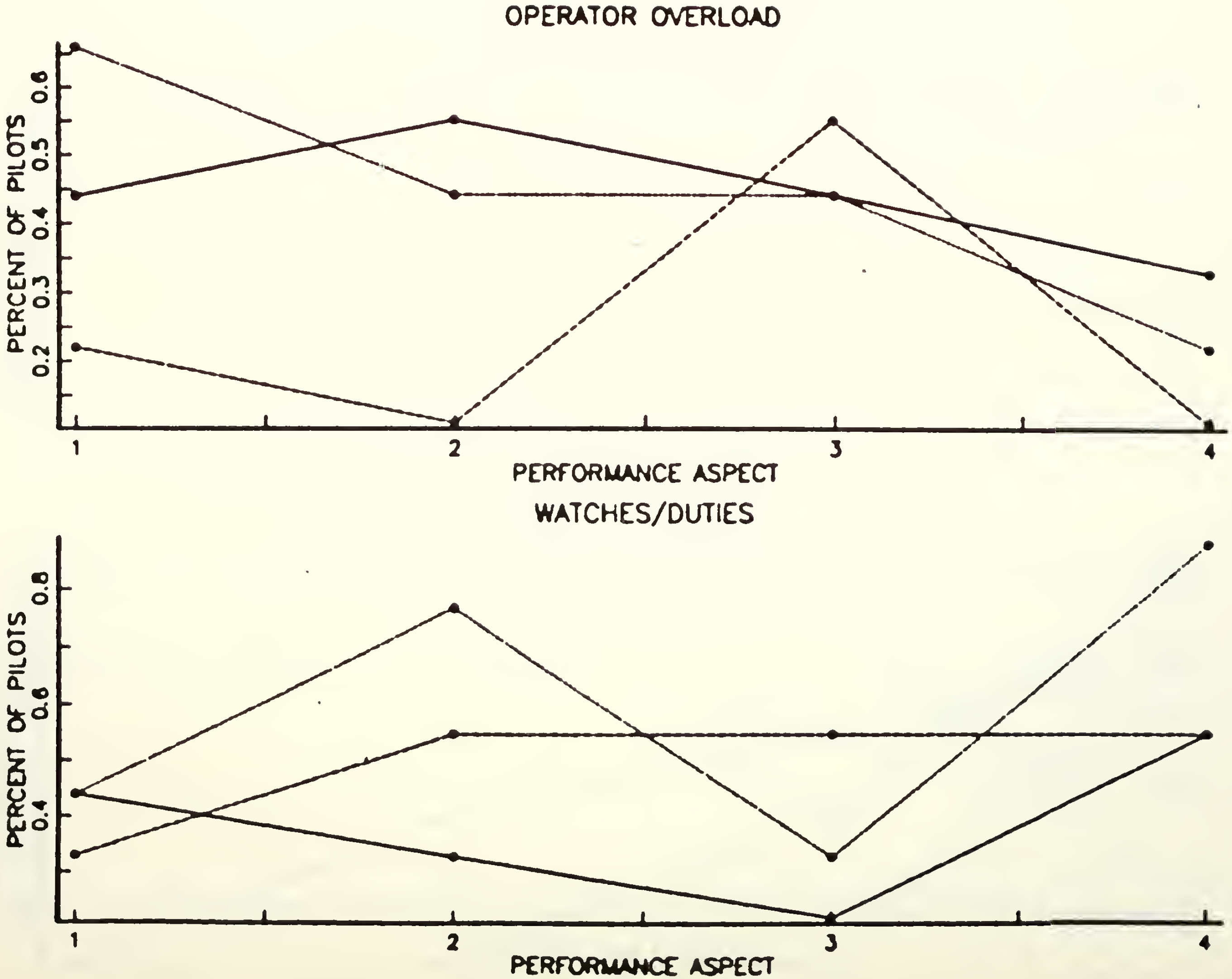

Figure I.4. Pilot Ranking Data

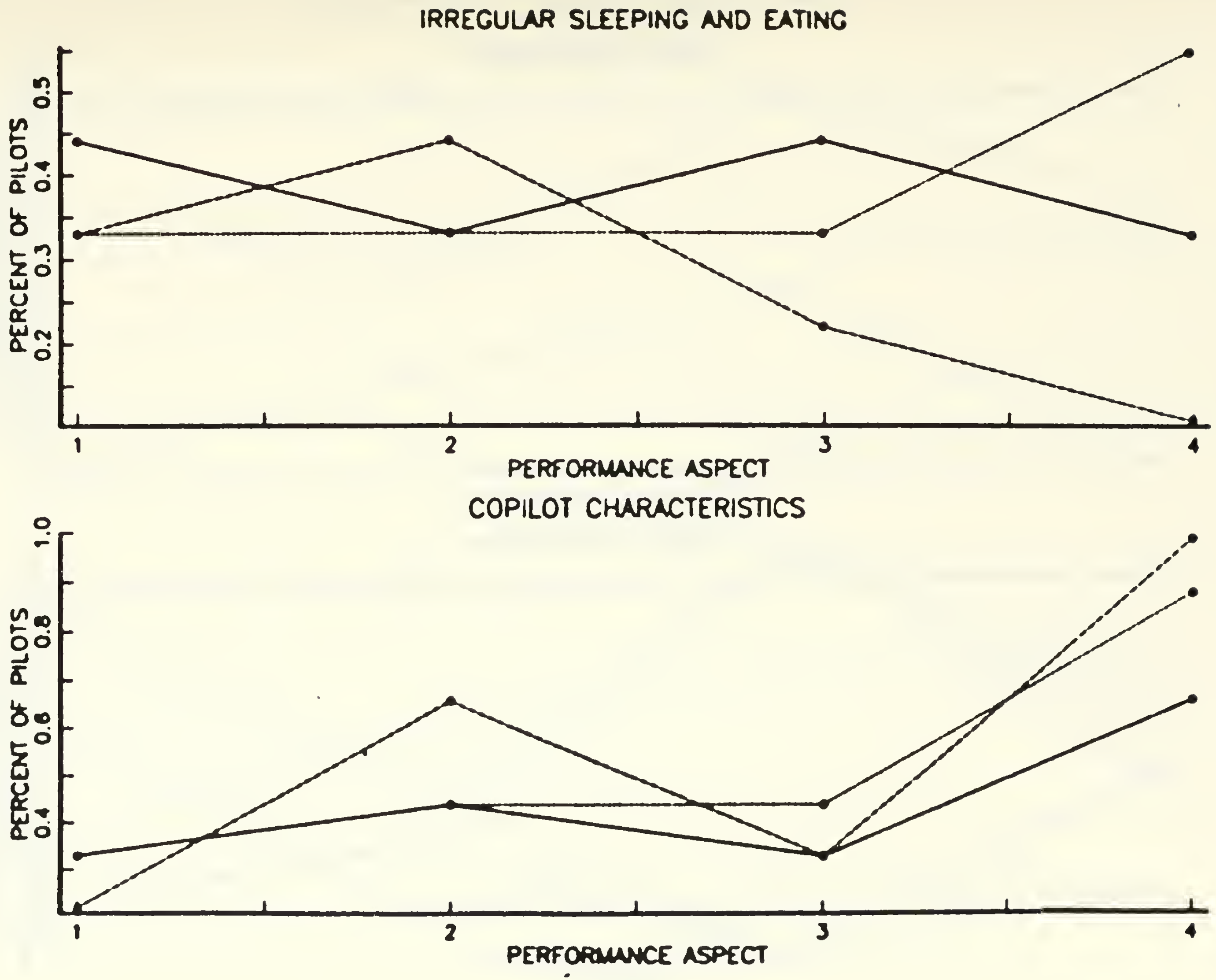

Figure I.5. Pilot Ranking Data

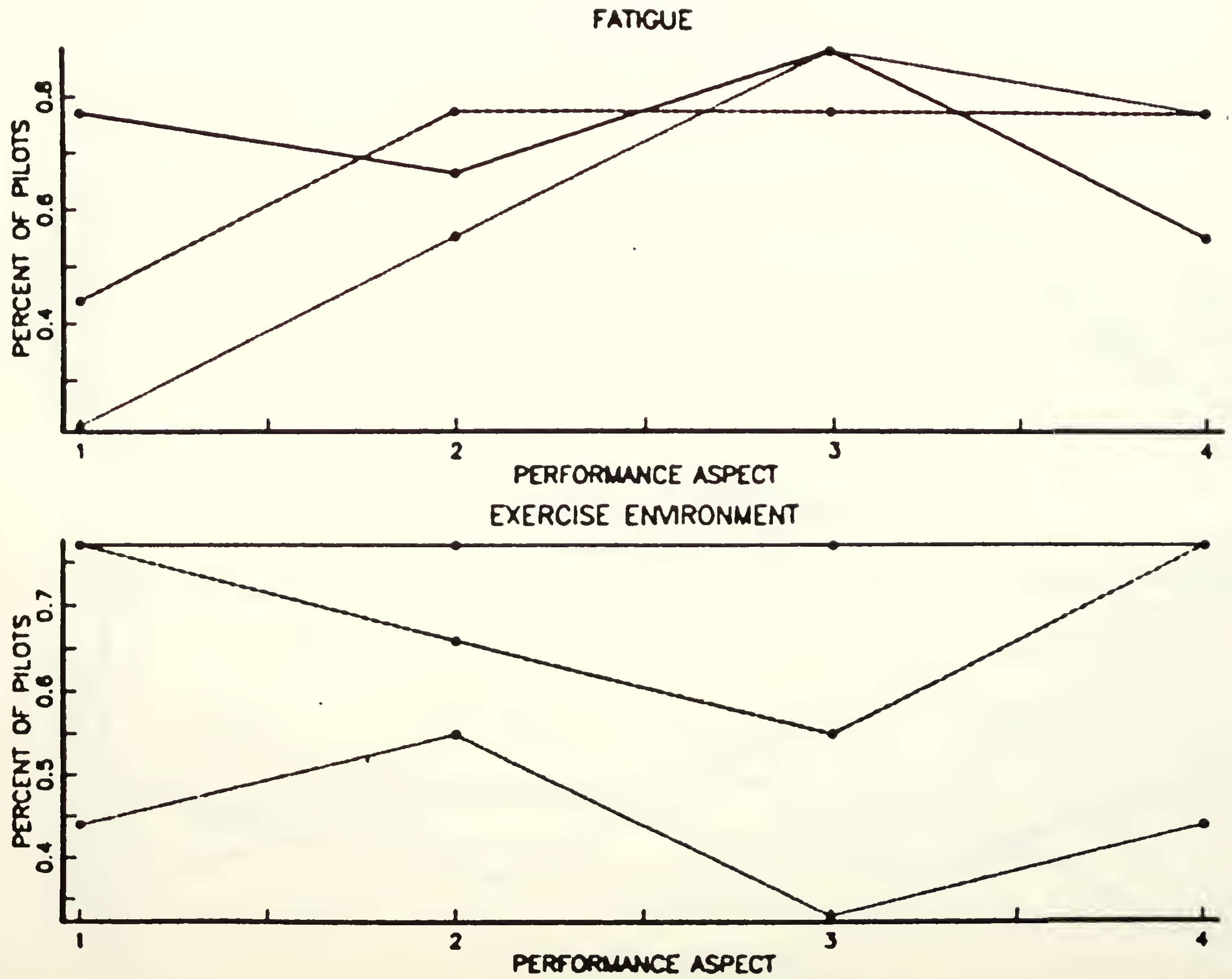

Figure I.6. Pilot Ranking Data

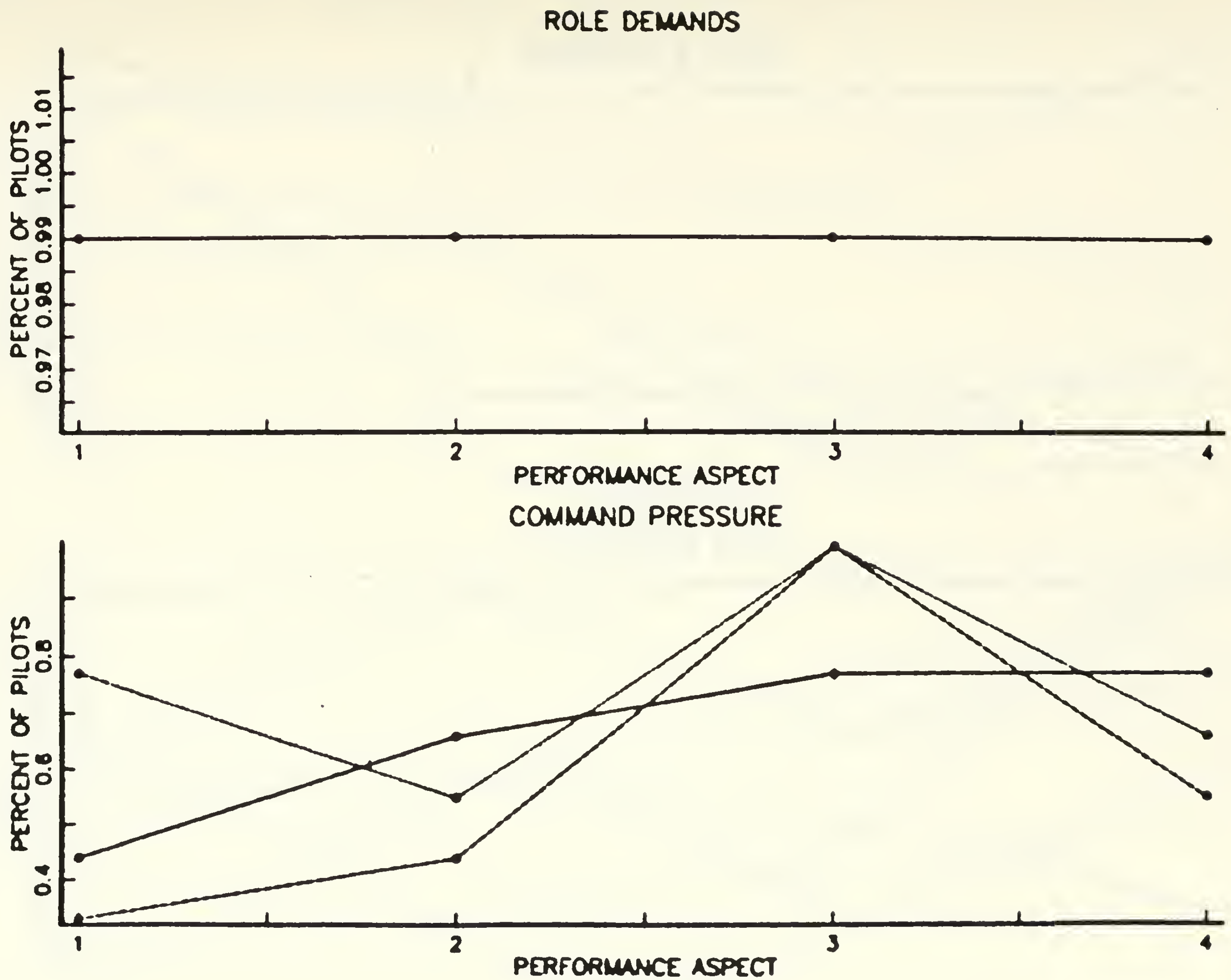

Figure I.7. Pilot Ranking Data

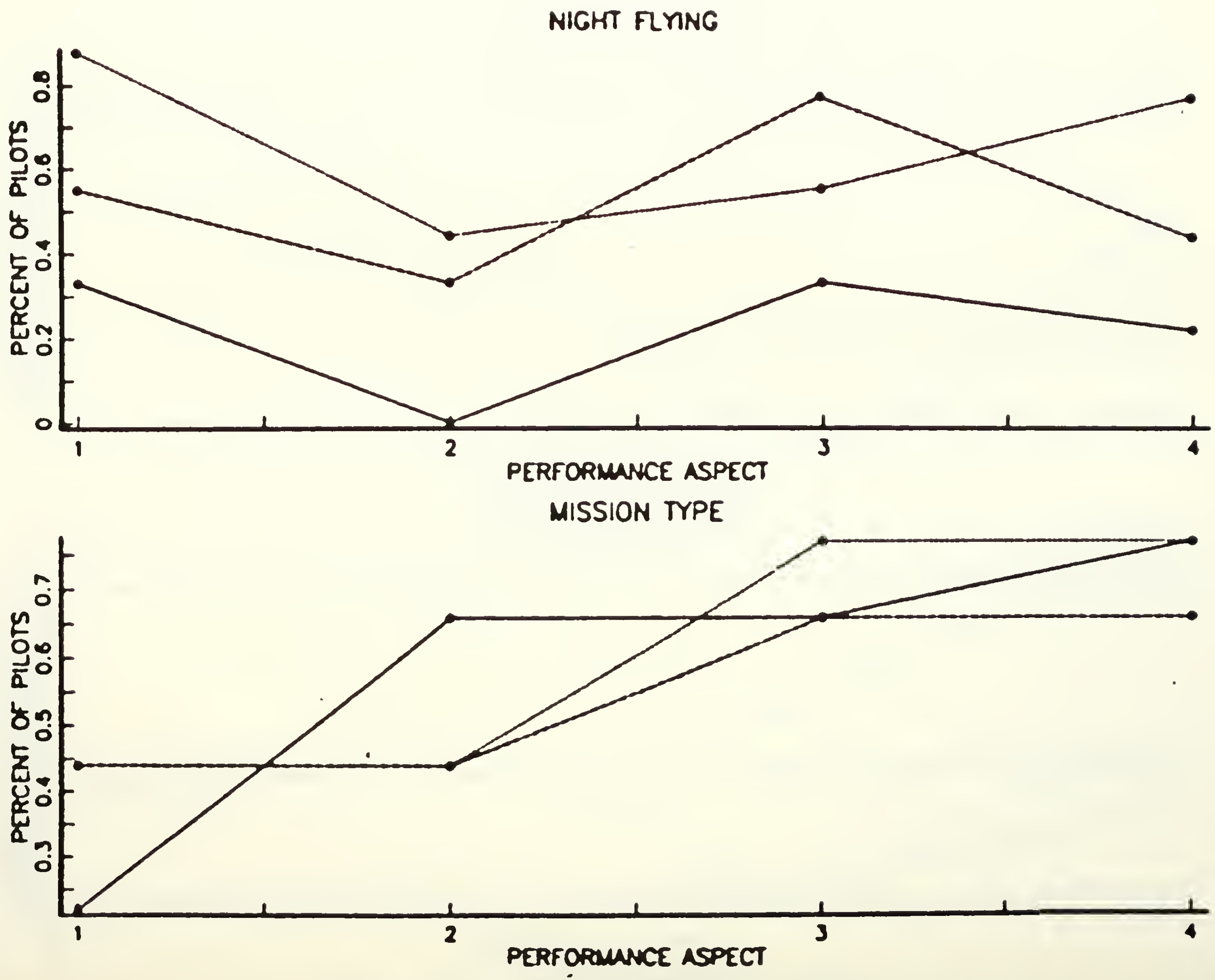

Figure I.8. Pilot Ranking Data

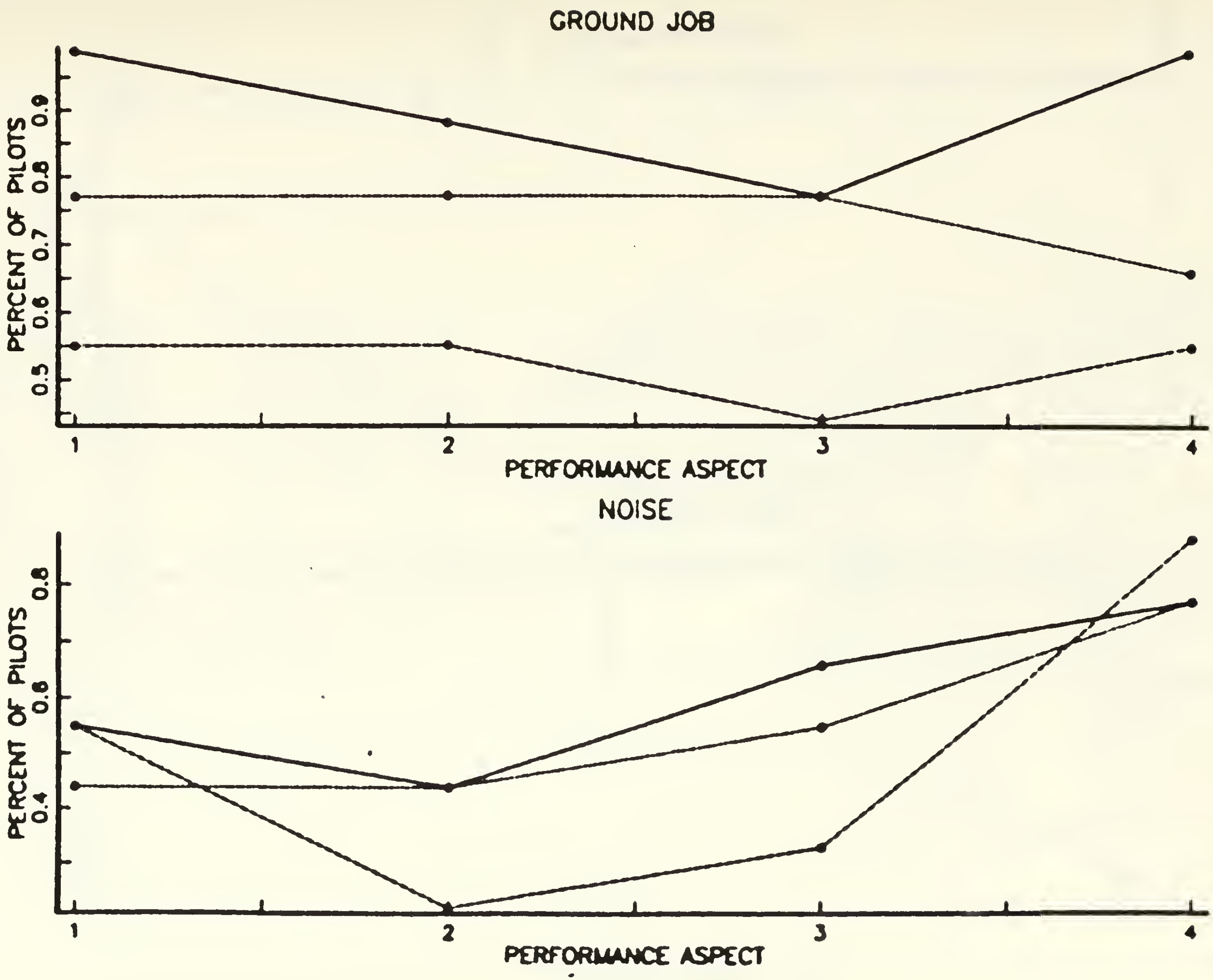

Figure I.9. Pilot Ranking Data

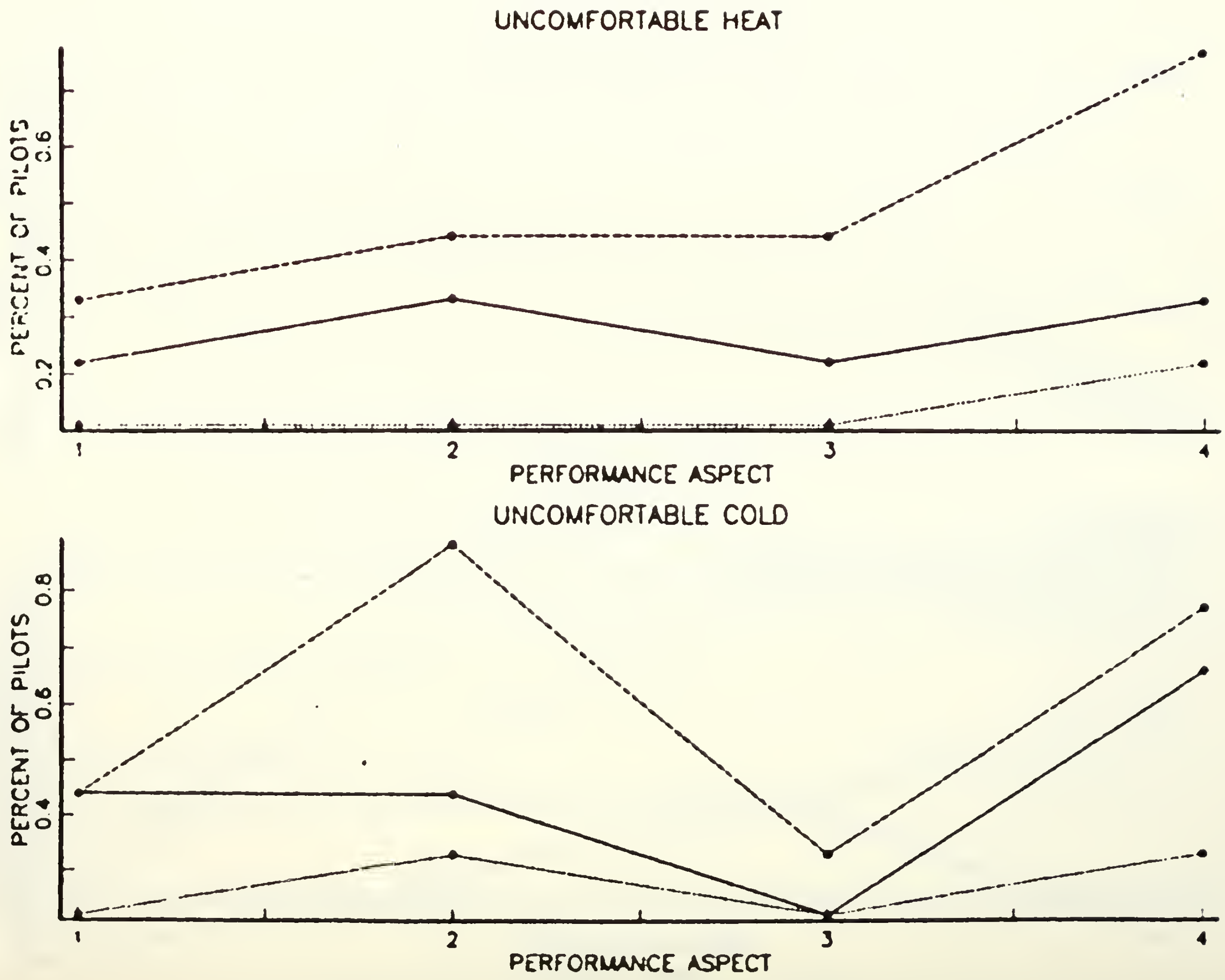

Figure I.10. Pilot Ranking Data

APPENDIX J

UNCONSTRAINED SORTING DATA

Mnemonic Code	Stressor
IP	irregular patterns of sleep and meals
EE	exercise environment
UH	uncomfortable heat
UC	uncomfortable cold
NO	noise
FC	helicopter flight characteristics
RD	role demands
MT	mission type
HD	helicopter cockpit, controls, and instrument design
ED	personal equipment design
WD	watches, duty, alerts
NF	night flying
BM	boredom/monotony
GJ	ground job
OO	operator overload
FA	fatigue
CP	command pressure
CH	characteristics of person you are flying with

Pilot 1

GROUP	STRESSORS IN GROUP
1	NO, UC, UH, FC, CH
2	FA, IP, EE
3	OO, NF, MT
4	HD, ED
5	GJ, WD, BM, RD, CP

Pilot 2

GROUP	STRESSORS IN GROUP
1	ED, BM
2	NF, OO
3	MT, FC, HD, NO
4	CH, RD, CP, GJ, WD
5	FA, IP, UH, UC, EE

Pilot 3

GROUP	STRESSORS IN GROUP
1	IP, FA, EE, WD, BM, OO
2	RD, GJ, CP
3	UH, UC, NO
4	FC, HD, NF, MT, ED
5	CH

Pilot 4

GROUP	STRESSORS IN GROUP
1	FA, IP, EE
2	GJ, WD, CP, RD
3	UC, UH, NO
4	MT, NF
5	FC, HD, ED
6	OO, BM
7	CH

Pilot 5

GROUP	STRESSORS IN GROUP
1	IP, FA, OO, WD, NF, MT
2	FC, ED, HD
3	UC, UH, NO, EE
4	CH, BM, GJ, RD, CP

Pilot 6

GROUP	STRESSORS IN GROUP
1	NF, MT
2	HD, ED
3	FA, IP, EE, WD, BM
4	NO, FC
5	UH, UC
6	OO, CH
7	GJ, CP, RD

Pilot 7

GROUP	STRESSORS IN GROUP
1	IP, WD, BM, FA, OO
2	EE, CH, MT, NF
3	FC, HD, ED
4	UC, UH, NO
5	GJ, RD, CP

Pilot 8

GROUP	STRESSORS IN GROUP
1	FA, UC, UH, BM, NF, OO, CH
2	ED, HD, FC, MT, NO
3	WD, IP, EE
4	CP, GJ, RD

Pilot 9

GROUP	STRESSORS IN GROUP
1	FA, WD, BM, IP
2	NO, UC, UH, EE
3	HD, FC, ED
4	NF, OO, MT
5	CP, CH, GJ, RD

Pilot 10

GROUP	STRESSORS IN GROUP
1	OO, NF
2	CP, MT, RD, GJ
3	FC, NO, CH, ED
4	EE
5	UH, UC
6	HD
7	FA, WD, BM, IP

Pilot 11

GROUP	STRESSORS IN GROUP
1	BM, FA, IP, NF, WD
2	NO, UC, UH
3	CH, CP, GJ
4	EH, FC, HD
5	MT
6	OO
7	EE
8	RD

Pilot 12

GROUP	STRESSORS IN GROUP
1	FA, IP, WD, EE
2	NF, OO, CH
3	FC, NO
4	UH, UC
5	ED, RD, BM, GJ, CP, HD
6	MT

Pilot 13

GROUP	STRESSORS IN GROUP
1	NF
2	HD
3	FA
4	UC, UH
5	FC, NO
6	EE, IP, WD, BM
7	CP, GJ
8	ED
9	RD
10	CH
11	OO
12	MT

Pilot 14

GROUP	STRESSORS IN GROUP
1	NO, FC, HD, ED
2	WD, GJ, CP, RD
3	OO, MT
4	FA, UC, UH
5	EE, IP
6	NF
7	CH
8	BM

Pilot 15

GROUP	STRESSORS IN GROUP
1	OO, NF
2	CH
3	UH, UC, ED, HD
4	FA, BM, IP, EE, WD
5	MT, CP
6	NO, FC
7	GJ
8	RD

Pilot 16

GROUP	STRESSORS IN GROUP
1	BM, IP, FA
2	NO, FC
3	OO, NF
4	ED, UC, UH, HD
5	CH
6	EE
7	WD, RD, CP, GJ
8	MT

Pilot 17

GROUP	STRESSORS IN GROUP
1	UC, UH
2	FA, IP, EE
3	CH
4	BM, MT, NF, OO
5	FC, NO, ED, HD
6	CP, RD, GJ, WD

Pilot 18

GROUP	STRESSORS IN GROUP
1	EE, IP, FA
2	UC, UH, FC, NO
3	BM, MT, OO, NF, CH
4	GJ, WD, RD, CP
5	HD, ED

Pilot 19

GROUP	STRESSORS IN GROUP
1	RD, CP
2	EE, IP, BM, FA
3	MT, CH, NF
4	WD, GJ
5	NO, FC, UH, UC
6	OO
7	ED, HD

Pilot 20

GROUP	STRESSORS IN GROUP
1	FA, IP, UH, UC, OO, WD, BM, NO
2	NF, EE, MT
3	RD, CP
4	GJ
5	FC
6	HD, ED
7	CH

Pilot 21

GROUP	STRESSORS IN GROUP
1	UC, UH, NO, HD, FC, ED
2	MT, OO, NF
3	CH, RD
4	BM
5	GJ, WD, CP, IP, FA, EE

Pilot 22

GROUP	STRESSORS IN GROUP
1	CP, GJ, WP, MT, RD, EE
2	FA, IP, UH, UC
3	HD, ED, FC, NO,OO
4	NF
5	CH
6	BM

Pilot 23

GROUP	STRESSORS IN GROUP
1	CH, CP, RD
2	HD, ED, UH, UC, NO, FC
3	FA, IP, WD, EE
4	GJ
5	BM, MT
6	OO
7	NF

Pilot 24

GROUP	STRESSORS IN GROUP
1	CP, WD, GJ, RD
2	UC, UH, NO
3	CH
4	NF, MT
5	HD, FC, ED
6	BM, EE, FA, IP, OO

Pilot 25

GROUP	STRESSORS IN GROUP
1	NF, OO
2	BM, EE
3	CH, MT
4	UC, UH, NO
5	FA, IP
6	ED, HD, FC
7	GJ, WD
8	RD, CP

Pilot 26

GROUP	STRESSORS IN GROUP
1	NF
2	CH
3	FC, HD, ED
4	MT, CP, RD
5	FA, BM, OO
6	NO, UH, UC
7	IP, EE, GJ, WD

Pilot 27

GROUP	STRESSORS IN GROUP
1	FA, BM, IP, UH, UC, OO
2	CH, NO, HD, FC, NF
3	EE, ED, MT, WD, CP, RD, GJ

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